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THE

RINCIPLES OF CHEMISTRY,

ILLUSTRATED BY

SIMPLE EXPERIMENTS.

BY

DR. JULIUS ADOLPH STÖCKHARDT.

PROFESSOR IN THE ROYAL ACADEMY OF AGRICULTURE AT THARAND, AND
ROYAL INSPECTOR OF MEDICINE IN SAXONY.

TRANSLATED FROM THE THIRD GERMAN EDITION,

BY

C. H. PEIRCE, M. D.

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PREFACE.

The following work has been translated, at the recommendation of Professor Horsford, as a good introduction to the study of chemistry.

Such alterations only have been made in the text, as were required to adapt it to use in this country. Other changes might have been desirable, such as substituting the *hydrogen* for the *oxygen* scale of equivalent weights, the *Fahrenheit* instead of the *Centigrade* thermometrical scale,* the adoption in every instance of a *scientific* instead of a *popular* nomenclature, &c.; but, after due deliberation, it was concluded not to depart from the original, except when absolutely necessary to do so. Where alterations in modes of expression, &c., have been made, the meaning of the author has been carefully retained.

In some few instances, the scientific nomenclature usually adopted in our chemical books has been departed from; but this could not well be avoided without somewhat marring the character of the original work. The changes, however, that have been introduced, will in no way confuse the more advanced student, even if they do not assist the learner.

---

* It is highly probable that the Centigrade thermometer will in a few years be generally adopted in this country for scientific purposes.

There has been in many cases great difficulty in rightly translating terms used in the arts and manufactures, for the obvious reason that there must be many *peculiar* technical terms in use in Germany, where arts and manufactures, such as porcelain-making, metallurgy, brewing, wine-making, &c., are so extensively cultivated.

An important part of the labor of translating has been performed by a friend, whose familiar knowledge of the German language has been to me of much value and assistance.

I am also under great obligations to the Rev. Dr. Francis, for his kindness in looking over the pages as they issued from the press, and for many valuable suggestions.

C. H. P.

INTRODUCTION.

THE rapid progress of experimental science during the last twenty-five years is to be ascribed, in great measure, to the fact that pupils, as well as instructors, have become experimenters. This is especially true with respect to chemistry. For every contemporary of Davy, engaged in experimental researches in this department, there are probably, at present, scores of persons occupied in the same field. The fruits of this labor are to be seen in the improved condition of manufactures; in the more substantial scientific basis upon which many processes, formerly altogether empirical, are now securely fixed; in the progress of agriculture, and the arts generally; and, to some extent, in the progress of medicine.

The course of instruction to which this greatly increased experimental investigation is chiefly to be attributed, namely, *the practical or experimental course*, bears the same relation to the study of text-books on chemistry that anatomical dissections do to the perusal of essays on operative surgery, or the solutions of problems in celestial mechanics to lectures on the architecture of the heavens. It is, beyond question, the most efficient method to secure a sound and available knowledge of the science, either elementary or more comprehensive.

Works designed to teach chemistry by experiment are already in use, both here and abroad, but most of them take for granted the possession of expensive apparatus, and a laboratory; scarcely any are designed to bring the practical study of the science within the means of the more elementary schools; — and none are to be found suited to the winter-evening firesides all over the country, where the younger and the more advanced of both sexes would delight in chemical experiments, did not the apparently necessary expense of apparatus forbid them.

It is to meet the latter two wants, as well as those of a general text-book, that the work of Professor Stöckhardt, edited by my late assistant, Dr. Peirce, is eminently suited.

The apparatus necessary for many of the most instructive and interesting chemical experiments would cost but a few dimes, and as many dollars would furnish the requisites for all, or nearly all, the most important experiments, if performed in the simple manner laid down in this book. A few tubes and flasks, a spirit-lamp, some corks, india-rubber and reagent bottles, almost complete the list. In consequence of the extensive adoption of this as an introductory work in the schools of Germany, sets of apparatus to accompany it are advertised by manufacturers.

The qualifications of this work, as a text-book for schools, are such as to leave little, if any thing, to be desired. The classification is exceedingly convenient. The elucidation of principles, and the explanation of chemical phenomena, are admirably clear and concise. The summary, or retrospect, at the close of each chapter, presenting at a glance the essential parts of what has gone before, could scarcely have been more happily conceived or expressed for the wants of a pupil or an instructor.

The book is also well adapted to the wants of teachers who desire to give occasional experimental lectures at a moderate expense,—and of those who design to commence the study of chemistry, either with or without the aid of an instructor.

E. N. HORSFORD,
Rumford Professor in the University at Cambridge.

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PART FIRST.

INORGANIC CHEMISTRY.

(MINERAL CHEMISTRY.)

INORGANIC CHEMISTRY.

CHEMICAL ACTION.

1. Every one knows that iron, heated to redness, changes into scales or cinders, and that, exposed to moist air or earth, it is converted into rust; that the expressed juice of the grape gradually turns to wine, and this, again, to vinegar; that wood in a stove, or oil in a lamp, disappears in burning; and that animal and vegetable substances in time putrefy, disintegrate, and finally disappear.

Iron cinders and rust are iron altered in constitution; iron is hard, tenacious, of a grayish-white color, and brilliant; by heating to redness it becomes black, dull, and brittle; on exposure to moisture it is converted into a powder of a yellowish-brown color. Wine is altered *must*, in which nothing of the sweet taste peculiar to the grape-juice can be perceived; but it has acquired a spirituous flavor, together with a heating and intoxicating power, which was not in the *must*. Vinegar is altered wine; it has an acid smell and taste, and has lost its spirituous flavor, as well as its exhilarating properties, its tendency being rather cooling and sedative. Search must be made in the air for the oil and wood which have disappeared during combustion; both these substances are converted into vapor or gas, and warmth and light are thereupon evolved with the phenomenon of fire. Of a similar nature are the changes which animal and vegetable substances undergo, if kept for a sufficient length of time; they are gradually converted, as they putrefy or decay, into various kinds of gas, some of which emit a very disagreeable odor.

Such processes, by which the weight, form, solidity, color, taste, smell, and action of the substances become changed, so that new bodies with quite different properties are formed from the old, are called *chemical processes*, or *chemical action*.

2. Wherever we look upon our earth, chemical action is seen taking place, on the land, in the air, or in the depths of the sea. The hard basalt, the glass-like lava, become gradually soft, their dark color passes into lighter, they crumble to smaller and smaller pieces, and are finally changed to earth. A potato placed in the earth grows soft, loses its mealy taste, becomes sweet, and finally decays. The bud, that sends forth a sickly pale shoot in a dark cellar, when exposed to the light and air grows up a vigorous, firm, and green plant, which, imbibing its nourishment from the moist air and soil, forms from their elements new bodies, not to be found previously in the water or the air. A delicate network of cells and tubes pervades the whole plant, imparting to it firmness; these we call vegetable tissues or woody fibre. We find in the sap, which passes up and down through these cells, albumen and other viscous substances; in the leaves and in the stalks, a

green coloring matter, — chlorophyll; and in the ripe tubers, a mealy substance, — starch. None of these substances are injurious to health; but if the potatoes grow in the dark and without soil, for instance, in the cellar, there is produced in their long pale shoots a very poisonous body, solanine.

The potato forms one of our most important articles of food. The starch contained in it is not soluble in water, but when received into the stomach quickly undergoes such a change that it can be dissolved or digested, and then introduced as a liquid into the blood. The blood comes in contact in the lungs with the inhaled air; the blood changes its color, the air changes its constitution, and the heat which we feel in our bodies is developed. We must conclude, from these changes, that chemical action is going on in our own bodies.

3. As long as a plant or an animal lives, the chemical processes are under the guardianship of a higher mysterious power, which is called the *vital force*, and by which they are constrained to furnish the materials for the structure of the animal or vegetable bodies. The vital force is, as it were, the architect who plans the building, and sees that the requisite materials are procured by the chemical processes, and worked up according to his will. Hereupon arise innumerable new bodies, which cannot be artificially imitated, as, for example, wood, sugar, starch, fat, gelatine, flesh, &c. They are called *organic compounds*, or animal and vegetable substances, in opposition to *inorganic* or mineral bodies, which may be artificially imitated by putting together their constituent parts. When life in an animal or vegetable ceases, the chemical powers obtain the mastery, and these, as if they were the grave-diggers of nature, fulfil the old motto, — "Earth to earth, and dust to

dust." The leaves of the potato plant become yellow, and then brown; they fall off, and are gradually converted into a dark powdery substance,—humus. In the course of time even this disappears, with the exception of a little ashes, which cannot take flight with the rest. What here it takes years to bring to pass, happens in minutes if we throw the dry leaves into the fire. The chemical action is in both cases quite similar,—the only difference consists in the time in which it occurs; it goes on rapidly, as combustion, under a strong heat, and slowly, as a process of decay, at a moderate temperature. But what appears to us annihilation is only change. The substances which have been, not annihilated, but only rendered invisible by combustion or decay, we find again under another form, with exactly the same weight, in the air; from the air, they are again drawn down to the earth by the chemical processes going on in living plants.

4. We see from this how the inscrutable power of the Almighty appointed the chemical processes for his servants, in order, by their agency, to produce the eternal vicissitude which we daily observe around us in all nature, and to call forth evermore, in uninterrupted succession, new life from death; thus it must be self-evident how improving and instructive for every thinking man is that science which explains to him this vicissitude, and opens to him a clearer insight into the wonders of creation.

This deeper insight will not only lead the mind of man to higher improvement and perfection, but must also fill it with greater admiration and profounder reverence for Him, who revealed to us in these wonders his unsearchable omnipotence and wisdom.

In another point of view, the interest in chemical knowledge will be most powerfully excited by the useful application which can be made of it in every-day life. Chemistry teaches the apothecary how to compound and prepare his medicines; it teaches the physician how to cure maladies by means of these medicines; it not only shows the miner the metals concealed in rocks, but aids him also in smelting and working them. Chemistry, in connection with physics, has been the principal lever by which so many arts and trades have been brought to such a degree of perfection within the last few decades, and by its means we have been supplied with the numberless conveniences of life that were not enjoyed by our fathers. It cannot be doubted that the farmer must at once regard chemistry as his indispensable friend, for it is this alone which acquaints him with the constituent parts of his soil, with the proper nutriment of the plants he wishes to cultivate, and with the means whereby he can enhance the fruitfulness of his fields.

5. *Chemical Force or Affinity.*—If a ball of iron be heated to redness, till a thick crust of scales is formed around it, and then weighed, it will be found to have increased in weight; consequently, it must have been supplied with something ponderable from the air. This ponderable substance is a species of gas, called oxygen; by its union with the iron it has become fixed, yet by other chemical processes it can be reconverted into its gaseous form. If this crust of iron is now exposed for a time to moisture, it will gradually become rust, and again weigh more than before; it has attracted and united to itself water, and more oxygen from the air. Accordingly, the crust consists of iron and oxygen, the rust, of iron, oxygen, and water, which have become most *closely united* with each other;—

they are chemically combined. There is a peculiar power, which is considered the cause of this intimate union, as, in general, of all chemical changes; it is called *chemical power* or *affinity*, and bodies that possess this capacity of uniting with each other are said to have an affinity for each other. Accordingly, iron at a red heat has an affinity for the oxygen of the air, and at an ordinary temperature it has also an affinity for water. A ducat changes neither its color nor its weight, whether at a glowing heat, or exposed to moisture; we conclude that gold possesses no affinity for oxygen or for water.

6. A force cannot be seen or grasped; we notice it only in the effects which it produces. If we would know whether a piece of steel possesses magnetic power, we apply a needle, and try whether this is attracted by it or not; we then conclude from its behaviour as to the absence or presence of magnetism. Precisely the same course, that of *experiment*, must be taken, in order to become acquainted with the chemical forces, the affinities of bodies for each other. Every experiment is a question put to a body, the answer to which we receive through a phenomenon, that is, through a change which we observe, sometimes by the sight or the smell, sometimes by the other senses. The question has just been put to iron and gold, whether they have an affinity for oxygen; the iron, converted into black oxide, gave an answer to this question, the unchangeable gold did not. Every change which we perceive, every new property which we observe in a body, is a letter in the language of chemistry. To learn this easily and thoroughly, it is above all things useful for the beginner to exercise himself in spelling, that is, in making experiments. To give directions for this is the ob-

ject of the present little work. Those experiments only have been introduced, which, on the one hand, can be performed easily, safely, and without great expense, and, on the other hand, seem best adapted to illustrate the chemical doctrines and laws, and to imprint them on the memory.

7. There are *four leading questions* which the chemist puts to the different natural bodies.

a.) *Of what are they composed?* Take, for instance, a piece of bone. How is it affected when strongly heated in a furnace? It becomes whiter, lighter, and less solid than before (bone-ashes). But how is it affected when heated in a covered vessel? It becomes lighter, and black (bone-black). If exposed to boiling water, or to steam, how is it affected? It becomes lighter, and remains white; but in the water is dissolved glue. How in muriatic acid? It becomes transparent; the bone-earth is dissolved, and a gristly mass remains, which, when boiled with water, turns to glue. What is the action of fire upon the glue? In a covered vessel it is converted into coal, in an open one it burns and disappears. These few experiments show that the bone contains a glue which is combustible, and an earth which is not so; they show, at the same time, that it is the carbonized glue which, in the second experiment, colors the bone-earth black, and makes it bone-black; that this glue is dissolved in water, but not in muriatic acid, &c. Glue and bone-earth are called the *proximate constituents* of bone, but by continued chemical processes these can be resolved still further, that is, separated into simpler constituents. In bone-earth are found phosphorus, a metal (calcium), and oxygen; in the glue, besides carbon, three other bodies, — oxygen, *hydrogen, and nitrogen.* These bodies can be decomposed no further by any known method of analysis, and are therefore called *simple bodies*, or *chemical elements*. There are now about sixty known elements, and almost every year adds to their number; but this increase is of little importance to chemical science or its applications, for it consists of elements which but very seldom occur. This separating of compounded bodies into simple ones is designated by the name of *analysis*.

b.) *What changes do bodies undergo, when placed in contact with other bodies?* Phosphorus, which is obtained from bones, is luminous in the air, and is gradually converted into an acid liquid; it unites with the oxygen of the air, as the iron did on being heated to redness. If the phosphorus is gently heated, this union is attended with a vivid combustion, and there is formed an acid body which is different from the former; to which, if chalk be added, a new body is formed, very similar to bone-ashes, which is artificial bone-ashes. The number of new bodies which may be produced by the union of the elements with each other, or with compound bodies, is infinite, and entirely different substances are often formed, according as the combination takes place under the influence of cold or heat, in water or in air, in greater or smaller quantities. This is *combination* or *synthesis*.

c.) *What useful application can be made of chemical theory and practice?* When the chemist discovers a new body, or a new property in one already known, or a new method of synthesis or analysis, he imparts his discovery to the apothecary, the physician, the farmer, the manufacturer, and the tradesman, that experiments may be instituted for the purpose of ascertaining whether any advantage, facility, or improvement can be derived for pharmacy, medicine, agriculject of the present little work. Those experiments only have been introduced, which, on the one hand, can be performed easily, safely, and without great expense, and, on the other hand, seem best adapted to illustrate the chemical doctrines and laws, and to imprint them on the memory.

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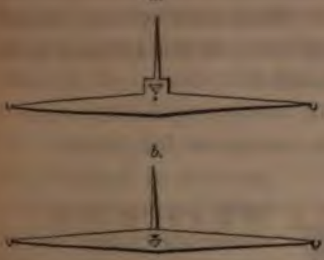
WEIGHING AND MEASURING.

8. *Weighing.* — The balance is to the chemist what the compass is to the mariner. The ocean was indeed navigated before the discovery of the compass; but not till after this could the sailor steer with confidence to a certain place, and recover his proper course, however often lost. And so, in chemistry, no systematic method of study could be pursued before the introduction of the balance. The balance is the standard, as well as the test, of chemical experiments; it teaches us how to ascertain the true composition of bodies, and shows us whether the questions put, the answers received, or the conclusions drawn from them, are correct or false. Hence it cannot be too strongly recommended to those commencing the study of chemistry to use the balance even in simple experiments. For the experiments described in this book, a common apothecaries' balance is all that is requisite.

Such a balance consists of a brass beam, with arms of equal length, through the centre of which passes a steel wedge-shaped axis, resting on a hardened plate, so that the beam, to the extremities of which the pans are attached, may easily vibrate. It is essential that the axis should be in the right place of the beam, a little *above* its centre of gravity, as in Fig. 1, *a*. The centre of gravity can be found by balancing the beam on its flat side, with the index attached to it, on a needle, and when the beam rests horizontally, the point of the needle designates the centre of gravity. If the axis be placed too low, *beneath* the centre of gravity, as in Fig. 1, *b*, the beam will overset, if one of the pans is more heavily loaded than the other. If placed directly in the centre of gravity, the balance itself will cease to vibrate when the beam is in an oblique position. When the axis is too high above the centre of gravity, the balance loses much of its sensibility. This latter defect occurs most frequently, but is easily remedied by lowering the axis.

Fig. 1.



9. The apothecaries' weight and the French decimal weight are those commonly used. The following is the table of the apothecaries' weight, which will answer for all the experiments given in this book: —

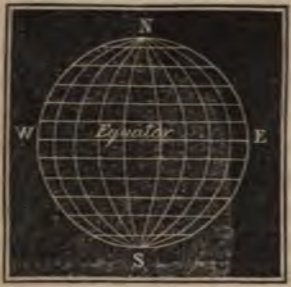
Pound.		Ounces.		Drachms.		Scruples.		Grains.
1	=	12	=	96	=	288	=	5760
		1	=	8	=	24	=	480
				1	=	3	=	60
						1	=	20

10. The new French system of *weights* and *measures*, which is now almost universally adopted by chemists, is characterized by great simplicity, all its divisions being made by ten; hence the name *decimal*

weight and measure. Its unit is derived from the
of our globe.

In order to define the different localities on
globe, imaginary circles, as is well known, have
drawn around it. Those which pass round the
from east to west, the largest of which is the equ
are called parallels of latitude (circles of latitu
those which pass round the earth lengthwise, inter
ing at the poles, *meridians* (circles of longitude).

Fig. 2.



parallels of latitude g
ually become smalle
wards the poles; the
ridians, on the cont
are all of equal size.
circle, N E S W N re
sents a meridian or c
of longitude. The fo
part of this circle,
what is the same th
the fourth part of the
cumference of our e
as N E, is the basis of the French system.
quadrant was divided into ten million parts, on
which was taken as the unit, under the name of *m*
A meter is about three feet and a quarter in len
The smaller measures are produced by dividing by
and are designated by Latin terms; the larger one
multiplying by ten, and are designated by Greek te

Smaller Measures.		Larger Measures.	
Meter.		Meter.	
Decimeter	$= \frac{1}{10}$ meter.	Decameter	= 10 me
Centimeter	$= \frac{1}{100}$ "	Hectometer	= 100
Millimeter	$= \frac{1}{1000}$ "	Kilometer	= 1,000
		Myriameter	=10,000

The system of weights was derived from the measure of length, in the following manner. A cubical box was taken, measuring exactly one centimeter in each direction, and this was filled with water at its greatest density (at the temperature +4° C.); the weight of this quantity of water was called a *gramme*. This is taken as the unit of the decimal weights, and is multiplied or divided by ten.

Smaller Weights.		Larger Weights.	
Gramme.		Gramme.	
Decigramme	= $\frac{1}{10}$ gramme.	Decagramme	= 10 gr.
Centigramme	= $\frac{1}{100}$ "	Hectogramme	= 100 "
Milligramme	= $\frac{1}{1000}$ "	Kilogramme	= 1,000 "
		Myriagramme	= 10,000 "

One gramme is equal to 15.44579grs. Troy.

One kilogramme is equal to 2lb. 3oz. 4.17dwt. Av.

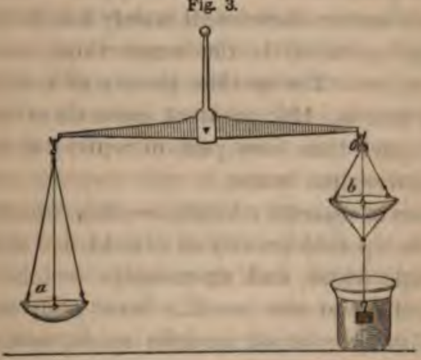
It is well enough known that the body whose weight is to be ascertained must be put into one scale, and in the other weights sufficient to restore the index to its original perpendicular position. The weight of a body thus determined is, in scientific language, called its *absolute weight*. Thus, a piece of sugar weighing two ounces has an absolute weight of two ounces; or, if a vessel be filled with two pounds and one ounce of water, this water has an absolute weight of two pounds and one ounce.

SPECIFIC GRAVITY.

11. ICE floats in water, iron sinks in it, because the former is lighter, the latter heavier, than water. But if we put a piece of ice in spirit it sinks, or if we put a piece of iron upon quicksilver *or mercury it* floats; consequently, *ice is heavier than spirit*, iron lighter than quick-

flask from the pan, and put the nails into the flask. A bulk of water will be displaced equal to that of the nails to determine its amount, replace the flask, after it has been thoroughly wiped on the outside, upon the pan and remove weights from the other pan until the equipoise is restored. The weights taken away (about 32 grains) form the divisor, and the half-ounce, or 240 grains, the dividend; the quotient $\frac{240}{32}=7.5$, is the specific gravity of iron, of which the nails were made.

Fig. 3.



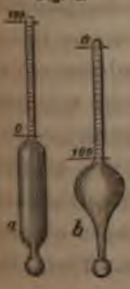
14. *Experiment.* — If we have to determine the specific gravity of a piece of iron, or of any other body which cannot be put into a flask, it must be fastened by a piece of fine thread to the pan of a common balance, (Fig. 3, *b*,) the cords of this pan having been previously shortened. Weigh the body first in air, and then in water, immersing it an inch deep. As it sinks, the opposite pan falls; consequently iron must be lighter in the water than in air. If the iron in the air weighed half an ounce, then, in order to restore the equilibrium, it will be necessary, as in the former experiment, to remove from the pan *a* 32 grains, equal to the weight of the bulk of water displaced by the iron. The loss of weight is the same whether the water be removed from the vessel or merely displaced within it. This forms the divisor, and 240

the weight of the iron in the air, the dividend, giving the quotient $\frac{240}{32} = 7.5$.

15. Every substance becomes lighter in water in proportion to the amount of water displaced; this is a law of nature. If it displaces less water than its weight in the air, it sinks; if more, it floats. Even very heavy bodies can be made to float by increasing their volume; ships are constructed of iron, although it is eight times heavier than water; a tumbler floats upon water, and yet the specific gravity of glass is from three to four times greater than that of water. A thick piece of iron, weighing half an ounce, loses in water nearly one eighth of its weight; but if it is hammered out into a plate or a vessel of such a size that it occupies eight times as much space as before, it then loses its whole weight in water, and will float, sinking just to the brim. If made twice as large, it will displace one ounce of water, — consequently twice its own weight; it will then sink to the middle, and can be loaded with half an ounce weight before sinking entirely.

16. *Areometer, or Hydrometer.* — The same body will sink to a greater or less depth in different liquids, — deeper in the lighter ones, and not so deep in those which are denser. This has suggested a very convenient instrument for determining the specific gravity of liquids, the *hydrometer* or *areometer.* This instrument consists of a hollow glass tube, made as represented in Fig. 4. The interior is hollow, and blown out into a bulb at the lower end, to cause it to float; the under part is loaded with quicksilver or shot, to give it a vertical position. The main tube serves to denote the depth to

Fig. 4.

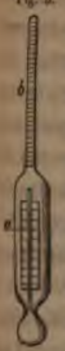


which it sinks in any liquid, by means of a scale of degrees, with which it is furnished. There are various instruments of this kind, especially adapted for determining the density of spirits, brandy, oil, lye, syrup, &c. If a hydrometer for weighing spirits is put into water, it sinks only to the lowest point on the scale 0° (Fig. 4, *a*); but in the strongest alcohol, which is much lighter than water, it sinks to the highest point, 100°. A scale for testing lye (Fig. 4, *b*) must, on the contrary, have the 0° point at the top of the scale, to which it would sink in pure water; for lye being heavier than water, the instrument would be more or less buoyed up in it, according to its strength. In hydrometers for lighter liquids, the degrees proceed from the bottom to the top, in those for heavier liquids from the top downwards. In most of these scales the degrees are arbitrary; and in order to convert them into the corresponding specific numbers, tables, constructed for the purpose, must be referred to.

17. *Experiment.* — Pour brandy into a cylindrical jar, and observe the degree which it marks on the hydrometer; then put it in a warm place, and, when lukewarm, again note the degree, which will be higher than before, as the heat has expanded the liquid, made it lighter, and consequently apparently stronger than it really is. (§ 22.) The specific gravity of all bodies, when warmed, is less than when cold. On this account, in determining the density of bodies, regard should be paid to their temperature, and it has been agreed to consider 15° C. (§ 24) as the mean temperature.

In the more accurate hydrometers, the mercury serving as the counterpoise has been ingeniously contrived also to indicate the degree of heat of the liquid, by connecting with it a graduated tube. The small

Fig. 5.



scale, *a*, (Fig. 5,) denotes the temperature, the long scale, *b*, the density. The small scale is frequently so constructed, that the degrees correspond to those on the long scale, and in order to guard against error it is only necessary to add the degrees below the mean temperature to the density, or to subtract from the density those above.

Gold is nineteen times, and silver ten times, heavier than water; gold alloyed with silver must, therefore, have a less specific weight than pure gold. The specific weight of brass is only = 8. Alcohol and ether are lighter in proportion to their purity and strength, while lye, syrup, the acids, &c., increase in density according to their purity. Hence it is evident how important it is, in many cases, to know the specific gravity of a body in order to judge of its quality.

THE ANCIENT DIVISION OF THE ELEMENTS.

18. *Matter and Forces.* — As we discern in ourselves the visible *body*, and its ruler, the invisible *spirit*, so we recognize in external nature *bodies* which we can handle and weigh, and *forces* or *powers* ruling these bodies and having no weight.

19. *Aggregation.* — The innumerable *natural bodies* which we meet with on the earth may be divided into three great classes; they are either *solid*, *liquid*, or *aeriform*, and each of these states in which bodies exist is called its state of *aggregation*.

Cohesion. — To divide a piece of ice into smaller fragments, a greater force is requisite than to separate water into minute portions; whence we infer that the particles of the solid ice adhere more strongly than those of the fluid water. A certain attracting power is regarded as the cause of this difference; it acts on the very smallest particles of matter, and is called *cohesion* or homogeneous attraction. In solid bodies, cohesion is stronger than in liquids, and in aeriform bodies hardly a trace of it can be perceived.

The Ancient Elements, so called. — Of solid bodies, the most widely diffused is earth; of liquids, water; and of the aeriform bodies, air. From this the ancient philosophers concluded that all solid matter was formed of earth, all liquids of water, and aeriform bodies of air; on this account they called them *elements*, or *primary matter*. They cannot now be regarded as such in a chemical point of view, since they have been decomposed into still more simple bodies; but they may be viewed as *physical* elements, that is, as types of the three aggregate states of bodies.

20. We have no absolute knowledge of the forces of nature, they having as it were a spiritual existence. We are nevertheless as firmly convinced of their reality as we are of the reality of our own spirit, for we know them by their phenomena and effects. A piece of iron, on being thrown into the air, falls to the ground, which is ascribed to the power of gravitation; if exposed to a moist atmosphere, it rusts, that is, it unites with the oxygen of the air. This is the result of chemical force; and the force of electricity can free the iron again from this union. By the force of magnetism, a piece of iron, when balanced on a pivot, takes a direction from north to south; by the force of heat it can be

melted, &c., &c. From this it appears that there are various forces, but it is not improbable that they have one common origin, in the same way that all the different powers of the mind, will, imagination, judgment, &c., are all referred to one single spirit.

Fire, the fourth of the old elements, may be regarded as the symbol of these forces. This also has lost its place among the chemical elements, since it is merely a phenomenon of chemical processes affording light and heat.

Of these old elements, fire (heat), water, and air play an important part in most chemical experiments; heat being influential in promoting chemical changes, and water being the most usual solvent of solid and aeriform bodies. The air deserves consideration in all cases, for almost all chemical experiments are performed in it, and it may exert injurious or beneficial effects upon them. These three so-called chemical elements will therefore first be more particularly considered.

WATER AND HEAT.

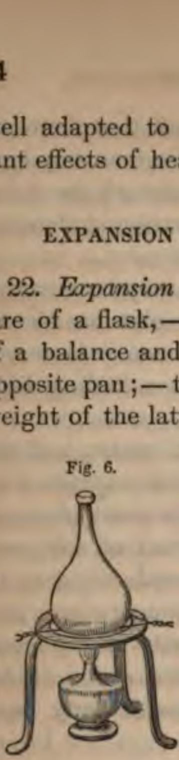
21. Water covers about three quarters of the surface of the globe; it exists sometimes solid, as at the poles, and sometimes fluid, as in warmer regions. In the form of rivers it intersects the land in all directions; while it rises in vapor into the air, and, forming clouds, returns in rain to the earth. Thus we find it in nature in its three aggregate forms, and it is obvious that these external differences have been effected by the agency of *heat*. Hence water is peculiarly

well adapted to serve as a study of the most important effects of heat.

EXPANSION BY HEAT, AND THERMOMETER.

22. *Expansion of Liquids.* — *Experiment.* — Take the tare of a flask, — that is, place it on one of the pans of a balance and equipoise it by weights put into the opposite pan; — then fill it with water, and ascertain the weight of the latter. Warm the flask on a tripod over a simple spirit-lamp, moving it round gently at first, that the flask may heat gradually. The water will soon rise, and part of it run over. When it begins to boil, remove the lamp and let the vessel cool, and the water will then sink deeper than it stood before. How much has been displaced is found by its loss in weight; it will amount to about $\frac{1}{23}$ of the first weight.

Fig. 6.



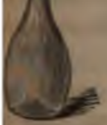
The burning spirit, or alcohol, heats the bottom of the glass vessel, which in turn communicates heat to the water. The heat expands the water, consequently it occupies a greater space than before, and part of it must run over. Hence it follows that warm water must be lighter than cold water. If a pitcher filled with two pounds of ice-cold water be afterwards filled with boiling water, it will weigh about an ounce and a half less. As it cools, it contracts again to its former density.

The same occurs with all other liquids, and indeed also with solids and gases: hence, it may be stated as a natural law, *that all bodies expand by heat, and con-*

act on cooling. But the amount of expansion is very
ifferent in different bodies at the same temperature;
lcohol, for example, expands two and a half times
ore, mercury two and a half times less, than water.
When fluids are to be bought and sold by measure, an
dvantageous application may be made of this prin-
iple. If a hundred measures of brandy or alcohol are
urchased in hot, and sold in cold weather, there will
e a loss of four or five measures; therefore we should
ain by buying in winter and selling in summer.

23. *Experiment.* — In order to observe more accurately the expansion of water by heat, adapt to a flask a cork, rendered so soft by gentle pounding that it may be exactly fitted to the opening by mere pressure; perforate the cork with a round file, and make the hole just large enough to admit a glass tube. Fill the flask with water, so that, when the cork is firmly pushed in, the water shall stand at about *a*, (Fig. 7,) and heat it as in the former experiment.

Fig. 7.



The water, which in the former experiment was displaced from the flask, in this
se rises in the tube, and the higher in proportion to
e smallness of its bore. By this means very slight
nges of space are rendered visible, and these de-
tions may be applied to the *measurement* of heat.
is is done by particular instruments called ther-
meters.

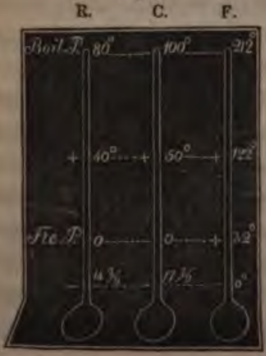
24. *Thermometer.* — Water might be employed for
asuring heat, by marking the boiling and freezing
ints, and graduating the intervening space; but
rcury is far better adapted to the purpose, as it
ls and freezes at *greater extremes* of temperature,

and more rapidly denotes the variations of heat and cold.

The vessel containing the mercury may also be regarded as consisting of a flask and tube, but which, instead of being joined by a cork, are composed of one entire piece. Having introduced into it a sufficient quantity of mercury, and sealed the open end by fusion, it is immersed in melting snow, and the point to which the quicksilver falls is marked *freezing point;* that to which it rises in boiling water, *boiling point.* The space between these two points can now be divided into degrees, to form the *scale.* The degrees below the freezing point are of the same dimensions as those above. There are several scales in use, though it is to be regretted that more than one has been adopted. The most common are the three following: — *Reaumer's* (R.), divided into eighty degrees; the centigrade of *Celsius* (C.), into one hundred; and *Fahrenheit's* (F.), into one hundred and eighty degrees. The difference between these can be easily seen in the annexed figure.

According to R. water freezes at 0° and boils at 80°; according to C. it freezes at 0°, and boils at 100°; according to F. it freezes at +32°, and boils at 212°.

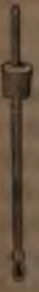
Fig. 8.



Fahrenheit, a philosophical-instrument maker, commenced counting, very strangely, not at the freezing point, but at 32° below it. His scale is still in common use in England, and the high numbers found in English reckonings are thus accounted for. In Germany, *Reaumer's* thermometer is used, except for scientific purposes, when the *Centigrade*, in common use in France, is employed, and it has been adopted in this work. In order to compare these thermometers with each other, it need only be remembered that 4° R. are as large as 5° C. or 9° F. In reducing Fahrenheit to Reaumer or Centigrade, if the degree be above the freezing point, 32° must first be subtracted, which process must be reversed in order to reduce the degrees of the other scales to those of Fahrenheit. To the degrees above 0°, the sign + is prefixed, to those below, the sign —.

A cylindrical thermometer, graduated to 300° C., like that in the annexed figure, is best suited for chemical experiments, as it can be easily adapted to a perforated cork, and then fitted to a flask, in which liquids are to be heated to a certain temperature. The degrees above the boiling point are to be divided off at distances equal to those below.

Fig. 9.



25. Quicksilver freezes at —40° C. In the northern regions of the earth a degree of cold of —50° C. has been observed, and by artificial means the temperature can be lowered to —100° C. When great degrees of cold are to be measured, alcohol is used in the construction of this instrument, as it does not congeal at —100° C.

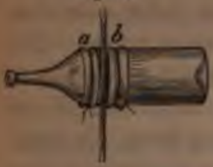
26. Quicksilver boils at 360° C., therefore its use must be limited to temperatures below this point. The high temperatures attending ignition are measured by the expansion of platinum bars, a metal which does not melt even in the hottest furnace. Such an instrument is called a *pyrometer*. By means of lenses, and by chemical action, a degree of heat of more than 2000° C. may be *produced*.

27. *Expansion of Solids.*—If an iron vessel, when cold, is just large enough to pass through the door of an oven, it cannot be removed from it when heated. The iron bands or tires of carriage wheels are applied while red-hot to the frame, and on cooling they contract and bind the wood-work together with great force. A metallic disk, which, when red-hot, fits exactly into a circular box, will, on cooling, become loose, and shake in it. The tire and the disk both become smaller on cooling. These examples show that solids also are expanded by heat, and contracted by cold, and explain many of the phenomena of common life. Clocks go faster in winter, and slower in summer, because the pendulums elongate in summer, and consequently vibrate slower, while in winter they become shorter, and vibrate more rapidly. A piano gives a higher tone in a cold than in a warm room, on account of the contraction of the strings; a nail driven into the wall becomes loose after a time, because the iron expands in summer and contracts in winter more than the stone or the wood, and thus the opening is gradually enlarged. For this reason, in the construction of railroads the rails must not be laid too close together; in the arrangement of steam-pipes, these must not be too firmly inclosed; in roofing, the zinc plates, instead of being nailed *together*, must overlap each other, that they may neither tear nor warp on alternate contraction and expansion.

Brittle bodies, as glass and porcelain, expand or contract so rapidly, by sudden heating or cooling, that they break.

Experiment.—Wind round a vial two bands of paper, *a* and *b*, Fig. 10, and secure them firmly with thread; pass a cord round the vial, between these folds of

Fig. 10.



paper, and move the vial quickly to and fro on the cord until the latter breaks. Then immediately pour cold water upon the place, and the glass will break as evenly as if cut. The sharp edges can be removed with a file. In this manner, common vials, and Cologne, and even larger, bottles, may be converted into vessels adapted to chemical and other purposes.

It is well known that heat is produced by the friction of two bodies upon each other; that by sliding quickly down a line or a pole by the hands, these will be burnt, and that rapid motion will ignite the axles of a carriage, unless they are well greased. Thus, in the above experiment, the friction produced great heat in the glass, the string emitted a burnt odor and broke, and great expansion of the glass was produced. When the outer surface was suddenly cooled by the cold water, the expanded particles at once contracted, and more rapidly in the external particles than in those of the inner surface, causing the fracture of the glass; and the more easily the greater its thickness. If the temperature had been slowly reduced, it would not have broken.

Thus, it is obvious, (*a*,) that glass and porcelain vessels intended for sustaining high temperatures, such as flasks, alembics, retorts, capsules, &c., should be thin, particularly at the bottom; and (*b*) that, when used, they should always be gradually heated and cooled.

The above method of heating glass by a cord furnishes the apothecary with a simple expedient for removing stoppers which are too firmly fixed in the bottles to be *taken out by turning* or tapping them.

Wind a cord round the neck of the bottle, and move it quickly until sufficient heat has been produced to loosen the stopper.

No two solids expand alike; the metals expand the most, and all solids less than fluids.

The expansion of *gaseous* bodies will be considered under the head of air. (§ 97.)

28. *Expansion by Cold.* — A remarkable exception to this law, of expansion by heat, and contraction by cold, occurs in the case of water.

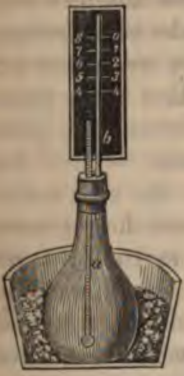


Fig. 11.

Experiment. — A large flask is arranged as directed in experiment 23, inserting also a cylindrical thermometer, *a*, through a hole made in the cork. The flask is filled with water to the top of the tube *b*, and placed in a vessel filled with snow. A strip of paper may be pasted on this tube, upon which the level of the water may be marked as the thermometer falls. The water as it cools will sink in the tube until the mercury stands at 4° C.; yet on cooling still more it does not fall any farther, as we should expect it would, but, on the contrary, it begins to rise again, and continues to do so till it reaches the freezing point. At 0° C. it stands at the same point as when its temperature was at 8° C. Water is accordingly the densest at +4° C.; all other liquids continue to increase in density as they cool.

29. However unimportant this exception may appear at first, our admiration must be the greater when we reflect upon its consequences. Were it not for this, our country would have the climate of Greenland.

The freezing of our waters, as the winter sets in, is principally owing to the coldness of the atmosphere. Consequently, the upper part of the water is colder and heavier, and sinks to the bottom; the warmer water ascends, becomes cold, and also sinks. If the water continually became denser, to its freezing point, this circulation would continue till the whole mass of water to its greatest depth reached 0° C., and a few cold days would suffice to convert all our ponds, lakes, and rivers into ice. This does not happen, because the circulation ceases when its temperature has fallen to 4° C.; when the water, though yet colder, becomes lighter, and floats on the surface. Thus, freezing can only take place at the surface, and the ice be but gradually formed. At a small depth below the ice, the water always retains the temperature of 4° C.

MELTING OF SOLIDS.

30. The expansion of bodies is the first general effect of heat; but in solid bodies another effect is observed; they change their aggregate state, they become liquid, they *melt*. Many of them become *soft* before melting, so that they can be kneaded; for instance, butter, glass, and iron; in this condition, glass can be bent and moulded like wax, and iron can be forged.

Experiment. — Hold a piece of a small glass tube in the upper part of the flame of a spirit-lamp, revolving it slowly between the fingers; when red-hot, it will be so soft that it can be bent into any shape desired. Thus are easily formed any of the numerous bent tubes required in chemical experiments. For softening larger tubes, a lamp with a double blast must be used, as this gives a much stronger heat than the simple lamp. To break a glass tube, a scratch is made upon it with a three-cornered file, at the place to be broken, and then it can be parted by gently pulling with both hands.

Most solid bodies become *suddenly fluid*, as ice, lead, &c.

31. *Experiment.* — Place one vessel containing snow or ice, and another containing a piece of tallow, on a warm stove, testing from time to time the melting substances with a thermometer; the temperature will remain stationary in the first vessel at 0° C, in the other at about 38° C., so long as any ice or tallow remains unmelted, but when the melting is complete it will commence rising. The degree of heat at which a body melts is called its *melting point.* Every substance has its own melting point, sometimes above and sometimes below the freezing point; for example, lead melts at above 300° C., silver at above 1000° C.; solid quicksilver at —40° C. If these two vessels containing water and melted tallow are placed in the cold, it will be observed that the tallow soon hardens at about +35° C., but the water not until the mercury has fallen to 0° C. Thus the congelation of fluids takes place at about that temperature at which they pass from the solid to the fluid state.

Many substances, coal for instance, have never yet been melted, and others have never been frozen, as, for instance, alcohol; but it is very probable that, when some method of producing the greatest degrees of cold and heat is discovered, we shall succeed in rendering all solid bodies liquid, and all liquids solid.

32. *Latent Heat.* — *Experiment.* — Put two vessels of equal size on the hearth of a warm oven, one of them containing a pound of snow at 0°, and the other a pound of water at 0°; when the snow is melted, re-

move them both. By the touch merely it will be perceived that the snow-water is still cold, while the water in the other vessel has become warm; and the thermometer will indicate that in the former the temperature is at 0° C., in the latter at 75° C. Both vessels have received equal degrees of heat, and when put into the oven were of the same temperature; the question then suggests itself, What has become of the 75° of heat imparted to the vessel filled with snow? The reply is, This heat has been absorbed by the snow, thus converting it into a fluid, — melting it.

Experiment. — Put one pound of snow at 0° C. into the vessel containing the water heated at 75° C., and then test with the thermometer; as soon as all the snow has disappeared, the quicksilver will fall to the freezing point. Consequently the snow has taken from the hot water 75° C. of heat, and has thus become liquid.

33. *Experiment.* — This heat has by no means been annihilated in the water, but is concealed there (latent), and continues thus hidden as long as the water exists in a fluid state. But it will again become free, or sensible to the touch, when the water assumes a solid form. This may be rendered obvious by sprinkling $\frac{3}{4}$ of an ounce of water upon $1\frac{1}{2}$ ounce of quicklime; the lime swells, becomes very hot, and finally crumbles into a fine powder. If this is weighed when cold, it will be found to have increased in weight by half an ounce; thus two ounces of slaked lime have been produced from an ounce and a half of quick lime; the quarter of an ounce of water missing has passed off as steam. The water alone could have effected this increase of weight by combining chemically with the lime; and it can exist there only in a solid state, as the slaked lime is an entirely dry pulverulent *substance.* This great devel-

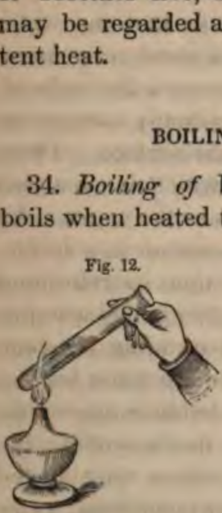
opment of heat can be explained thus: partly because the water, in becoming solid, gives up the heat which it had absorbed in passing to the fluid state, and partly because of the chemical combination between the two bodies taking place with great energy. *A disappearance of heat always ensues when solid bodies become fluid; but an evolution of heat, on the contrary, when liquid bodies become solid;* and thus is explained very simply, for example, why the air remains cool when the snow and ice are melting in the spring, and why the weather moderates on the fall of snow.

That heat which is felt by us, and which is indicated by the thermometer, is called *free heat;* it has but a feeble affinity for bodies, and easily leaves them on cooling. That imperceptible heat on which the fluidity of liquid bodies depends, and which on freezing escapes or becomes free, is called *latent heat.* Hence a fluid may be regarded as a combination of a solid with latent heat.

BOILING AND EVAPORATION.

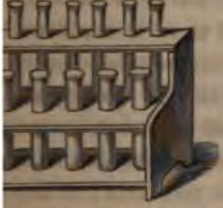
34. *Boiling of Water.* — Water, as is well known, boils when heated to a certain temperature.

Fig. 12.



Experiment. — Water, to which some sawdust has been added, is heated in a test-tube over a spirit-lamp. The tube is held by the upper part, and rotated for some minutes between the fingers, that the flame may have equal access to all the lower parts of the tube. If the water be carefully observed, it will be seen that the sawdust ascends on the upper ice of the liquid, and descends in the lower strata; varm water, becoming lighter, rises upwards, while older, consequently heavier, water sinks; the water lates. In consequence of this circulation, the heat-f fluids takes place more rapidly when the heat is applied *beneath.* Test-tubes are cylindrical glass vessels with rounded bottoms. To prevent their breaking on the application of heat, the bottom must be thin, and blown of a uniform shape. A simple wooden rack, as in the ed figure, serves as a convenient stand for

Fig. 13.



Experiment. — Repeat the former experiment, using instead of the tube a flask, and omit the sawdust, so that the water may remain clear; in a short time many little bubbles will appear on the walls of the flask, which will gradually increase in size, and rise towards the surface. These bubbles consist of air, which is expanded by heat and expelled from the water. All spring-water contains some air in solution, and to this is chiefly due its refreshing taste, which is not found in boiled water or in that which has been standing for some time. Afterwards, when the water has become quite hot, larger bubbles appear on tter part of the flask, which, also ascending, be-smaller and entirely disappear before reaching the of the water; they consist of aeriform water), which condenses as *it comes* in contact with

. 14.

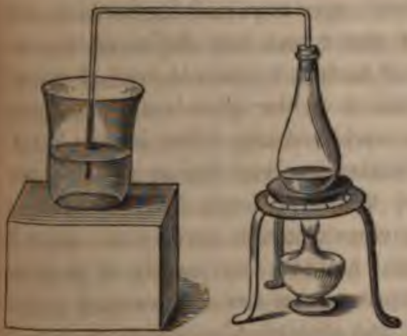
the cooler liquid above. The collapsing of the particles of water at the places where these steam-bubbles disappear occasions that peculiar noise which precedes boiling, and which is commonly called the *singing* of the water. When the whole mass of water is heated to 100° C., these bubbles no longer condense, but rise to the surface, where, surrounded by a thin film of water, they remain quiescent for a few seconds, and then, their watery mantle again sinking, they finally burst. This is the *boiling* of water. It boils at 100° C.; other liquids boil more readily,—alcohol, for instance, at 80° C.; others again more difficultly,—mercury, for instance, at 360° C.

35. *Steam.*—The space above the boiling water in the interior of the flask appears vacant, but it is in fact filled with aeriform water, which has displaced the air that was in it. This aeriform water is called *steam.* It is almost 1700 times lighter than water, because a quantity of water yields nearly 1700 measures of steam at 100° C. Within the flask the steam is transparent and invisible, but in the open air it ascends in the form of white clouds, which greatly increase if cold air is blown into the flask by means of a glass tube. On cooling, the transparency of the vapor is disturbed, on account of the formation of drops of water, so small and light as to float in the air. Clouds also consist of this partly condensed vapor. As the condensation increases, the drops become so large and heavy, that they descend as rain. A thermometer immersed in boiling water indicates 100° C.; if placed in the steam immediately above, it shows the same; and this temperature will not rise higher, however long the boiling be continued, or however strongly the flame of the lamp be urged. This is similar to what occurs in

the melting of snow; heat disappears, and its disappearance proceeds from the same cause in both cases; steam requires heat for its existence as such, and is so intimately combined with it that the excess is no longer perceptible,—it is latent. If water may be regarded as a combination of ice with latent heat, so steam may be considered as a combination of ice with still more latent heat; which latter becomes free again on the conversion of steam into water.

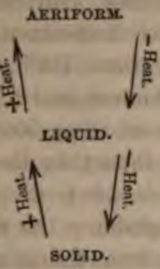
36. *Experiment.*—Adapt the shorter limb of a bent glass tube, by means of a perforated cork, to the neck of a flask, and pass the longer limb to the bottom of a beaker-glass or common tumbler. Pour into each of these two vessels two ounces and a half of ice-cold water, and gradually heat the glass upon a tripod until it boils. Note the time required for this operation. Continue the process until the water in the beaker-glass begins to bubble, and note also the time, which will be found the same as that required for heating the water in the flask. The steam formed in the flask has no other outlet than through the tube into the water, where it condenses, until the contents of the second glass reach the temperature of 100° C., and boil.

Fig. 15.



Both of the vessels must now be weighed; and it will be found that the flask *weighs half* an ounce less and the beaker-glass half an ounce more than before; consequently, half an ounce has passed from the former as steam, and has been condensed again in the latter; and yet this half-ounce of steam, which itself was not hotter than 100° C., could heat to the boiling point two ounces and a half of ice-cold water. What is the source of these 500 additional degrees of heat? They were latent in the steam, and, on its being condensed, were set free. These were caused by the heat of the spirit-lamp, as must be obvious from the above-noted amount of time consumed. Assuming that the time required to boil the water in the first flask was ten minutes, and also ten minutes for boiling the water in the second vessel, it follows, that the same amount of heat which was required for heating two ounces and a half of water was only sufficient to evaporate half an ounce of water; the whole heat given out in the last ten minutes from the spirit-lamp must consequently have been converted into latent heat. If half an ounce of boiling water received during the evaporation the amount of 500° of heat, then the steam evolved must have given off just as much heat when it again assumed a liquid state; consequently, it must be able to raise the temperature of two ounces and a half of water at 0° C. to that of 100° C.

The property of steam to absorb a large quantity of heat, and to part with it again during condensation, peculiarly adapts it for the heating of other bodies, the burning of them being thus guarded against, as the heat of steam in open vessels can never exceed 100° C. Apothecaries avail themselves of steam in the preparation of infusions, decoctions, and extracts; it serves for many of the processes of cookery, and for the distillation of spirits; it is employed in dyeing and bleaching establishments, and is often resorted to for heating apartments, buildings, laundries, &c.



The increase and decrease of heat produced by change of the aggregate state of bodies will be made clear by the annexed diagram. As the steam ascends in the direction of the arrows (by liquefaction and evaporation) heat becomes latent, and as it descends (condensation of vapor and congelation of fluids) heat is liberated.

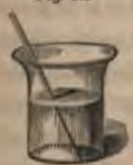
37. *Aqueous Vapor.* — Water exposed in a vessel to the open air disappears in summer more rapidly than in winter; the heat of the air renders it aeriform, — it *evaporates*. The same happens as in evaporation over the fire, only in the former case evaporation takes place without any visible motion of the water, owing to its becoming aeriform, not throughout the whole mass at once, but upon the surface only. Vapor rises in an invisible form in the air. Warm air, indeed, receives more of it than cold, but a fixed quantity of it only for each temperature. Thus one hundred measures of air at 0° C. absorb two thirds of a measure of vapor; at 10° C., one measure and a quarter; at 20° C., two and an eighth measures, &c. If the air has not yet absorbed all the vapor which it can, it eagerly takes up more, as, for example, when one hundred measures of air at 20° C.

contain only one or one and a half measures of vapor; it is then called *dry air*, and wet articles are soon dried in it by rapid evaporation. But if it be already saturated with vapor it is called *moist* air; and damp articles cannot be dried in it, or at least but slowly. If yet more vapor be added to this saturated atmosphere, or if it be cooled, then the excess separates in visible particles, called *mist* or fog when they lie upon the surface of the earth, and *clouds* when they float in the higher regions of the atmosphere. The white smoke which in winter is seen rising from the chimneys, the visibleness of the breath in frosty weather, and the smoking of rivers in winter and after a storm, are phenomena of the same kind.

38. If the cooling of the air is occasioned by a cold solid body, the vapor is then condensed in small drops of water, as may be observed on the outside of a cold glass when brought into a warm room, and the deposit of moisture on the inside of our window-panes, when cooled by the external cold air. The temperature at which this occurs is called the *dew-point*, signifying the temperature at which the air is saturated with vapor.

Experiment. — Fill a tumbler one quarter full with cool water, place in it a thermometer, and at short intervals gradually add ice or cold water, until moisture begins to deposit on the outside of the glass. Then observe the degree indicated by the thermometer, which is the dew-point. If much cold water must be added before the glass clouds over, that is, if the dew-point is much lower than the temperature of the air, fair weather may be expected; while, on the contrary, if the difference between the dew-point and the temperature of the air be

Fig. 16.



ut slight, rain may soon be expected, as then the air equires but a slight addition of moisture or increase of cold to become saturated. Instruments by means of which the amount of moisture in the air is ascertained are called *hygrometers*. Many substances readily imbibe moisture from the air, and become damp; such bodies, for instance, as catgut, carbonate of potassa, sulphuric acid, fresh barley-sugar, &c., are called *hygroscopic*.

39. *Evaporation* may be accelerated, not only by heat, but also by a current of air, because by this means the air above the surface of the fluid, which is charged with vapor, is removed and replaced by a drier, and, as it were, more thirsty air, which takes up the vapor more rapidly and abundantly than the former. For this reason, the earth dries rapidly after rain, when followed by a high wind, and hence it is necessary in kilns, laundries, drying-rooms, &c., to arrange them in such a manner that the air, when saturated with moisture, may be constantly replaced by dry air.

40. That *heat disappears* during slow as well as rapid evaporation (§ 36) may be readily illustrated by the following experiment.

Experiment.—Fill a tube half full of water, and fasten securely round the bulb of it a piece of cloth; saturate the cloth with cold water, and then twirl the tube rapidly between the hands; presently the water in the tube will become sensibly colder, and the degree of cold may be accurately determined by the thermometer. Moisten the cloth with ether, a very volatile liquid, and twirl it again in the same manner as before; by which means its contents, even in summer, may be convert-

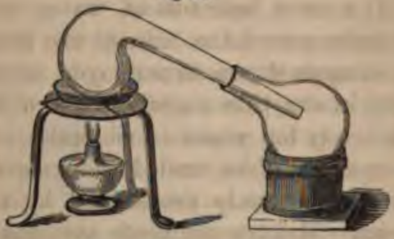
Fig. 17.

ed into ice. Water evaporates slowly, ether rapidly; and both require heat for their conversion into vapor, and in the above experiment they obtain this heat from the water in the bulb, which is of course the reason of the water becoming cold. On this principle, one feels cool on just leaving the bath, when invested in damp garments, or when the floor of a hot apartment is sprinkled with water. It explains, also, how man is enabled to support the scorching sun of the hottest climates, and even to endure a heat of 100° C., without his blood exceeding the temperature of from 38° to 40° C.; it is owing to the more copious perspiration, which, by evaporation, renders all the heat above 40° C. latent. If we blow on hot soup, it is also the increased evaporation which cools it more rapidly; but if we blow on the cold hands in winter, they become moist and warm, because the latent heat contained in the vapor of the breath is set free, as the vapor is condensed into water.

41. *Distillation.* — If evaporation be carried on in a close vessel, the water may be collected as it forms.

Experiment. — A small glass retort is half filled with water, and heated; the steam, as it forms, passes through the neck of the retort into a glass receiver, contained in a vessel filled with cold water, and is there condensed. That the refrigeration may take place more rapidly, the receiver is covered with coarse blotting-paper, which is frequently moistened by cold

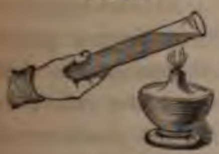
Fig. 18.



water. This operation is called *distillation* (from *distillare*, to drop), and the pure water obtained is said to be *distilled*. It is purer than spring-water, for this reason, that the non-volatile, earthy, and saline portions contained in all spring-water do not ascend with the vapor, but remain in the retort. By this means very volatile bodies also can easily be separated from less volatile ones; as brandy from the less volatile water. Copper stills are usually employed for distillation on a large scale, and for condensers vats are constructed, holding serpentine pipes, or *worms*, which present a greater condensing surface than if the pipe had passed directly through the vat. The cold water with which the vats must be filled is very soon warmed by the heat liberated in the condensation of the steam, and must occasionally be renewed by leading off the hot water from above, and letting in a fresh supply of cold water beneath.

DIFFUSION OF HEAT.

Fig. 19.



42. *Conduction of Heat.* — *Experiment.* — A test-tube, nearly filled with water, is held over a spirit-lamp, in such a manner as to direct the flame against the upper layers of the water; the water will boil at the top, but remain cool below. If mercury is treated in a similar way, its lower layers will gradually become heated. The particles of mercury will communicate the heat to each other, but not so the particles of water. Substances through which, as in mercury, heat rapidly passes, are called *conductors*; but bodies which comport

like water are called *non-conductors* of heat. In the former class are included particularly the metals, and in the latter, stone, glass, wood, snow, water, and especially cloth, fur, linen, straw, paper, ashes, &c.

The *conductors* are readily heated, and soon become cold again, as is well known to be the case with iron stoves. A piece of iron feels hotter in the sun and colder in the shade than a piece of wood at the same temperature. The explanation of this delusion of the sense of touch is, that the warm iron conducts the heat more rapidly to the hand, while the cold iron withdraws it more rapidly than the wood is capable of doing.

The *non-conductors* of heat are slowly heated, and also slowly cooled; for this reason, stoves constructed of brick (the Russian stove) and those made of Dutch tiles, a preparation of clay, retain their heat longer than iron stoves. Non-conductors are frequently employed both for preventing the quick heating and the quick cooling of bodies. Vessels of glass and porcelain are placed on sand (a sand-bath) or ashes, to heat them gradually, and thus guard against their breaking. If a hot liquid is to be poured into them, it must be done by small portions at a time, twirling the vessels round for some minutes before adding more.

On removing a vessel from the fire, the precaution should be taken never to place it while hot on metal or stone, but always on some non-conductor, such as straw (straw rings), wood, paper, cloth, &c.; as they are often cracked by sudden cooling and contraction, which is also frequently caused by a current of cold air. Doors of furnaces, ladles, &c., are provided with wooden handles to prevent those using them from being burnt. Should a person desire to hold a flask or a test-tube while liquids are boiling in them, he must wrap round them several folds of paper, or tie round them a piece of twine, in order that they may serve as a non-conductor between the glass and his fingers. By inclosing substances in non-conductors, the entrance of cold, or, more correctly, the departure of heat, may be prevented; this principle is illustrated in our method of clothing, in the protection given to our wells and trees by covering them with straw, in the preservation of the seeds of plants by snow, and in numerous other phenomena of daily occurrence. Hence non-conductors are frequently called preservers of heat.

43. *Radiation of Heat.* — By conduction, bodies can communicate or abstract heat only when in contact. But heat is felt even at some distance from a fire or from a heated stove, and the earth is warmed by the sun, although a space of millions of miles is between them. This sort of heating is called *radiation of heat.*

Experiment. — Envelop three tumblers with paper, one with silver paper, another with white, and a third with dull black paper, and place them in the sun; a thermometer will indicate that the tumbler with the black paper is heated the most, and that with the silver paper the least, and yet all these vessels have been equally exposed to the rays of the sun. This difference is explained on the principle, that the sun's rays are reflected from light-colored and shining bodies, whilst they are absorbed by those which have a dull, dark color. From this absorption it would seem that the light of the sun's rays is converted into heat. It explains why black clothes keep us warmer than white ones; why the snow melts more rapidly when soot or dark earth is scattered upon it; and why grapes and other fruits ripen quicker against dark walls than against those having a light color.

If hot water is poured into the tumblers enveloped with paper, and the cooling of it noted by the thermometer, the contrary effect will be observed; the glass covered with black paper will first become cold, and that wrapped in silver paper the last; because bodies with dull surfaces radiate the heat more rapidly than those with polished surfaces. For this reason, coffee retains heat longer in a bright than in a tarnished pot; a stove of glazed Dutch tiles remains hot longer than another of unglazed tiles; a smooth sheet-iron stove, longer than a similar one of rough cast-iron, &c.

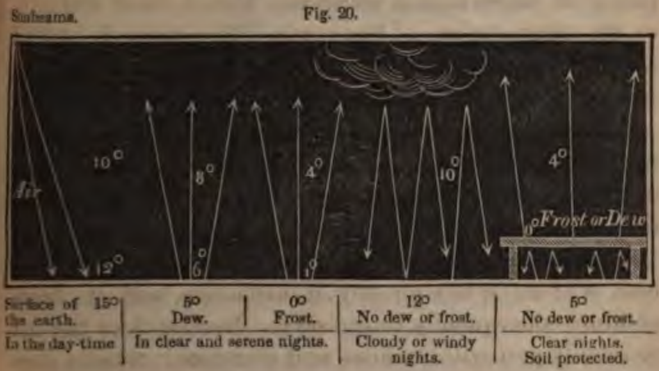
The radiation of heat enables us to explain some of those common natural phenomena which otherwise would remain obscure. Why do not the rays of the sun, even in the hottest summers, melt the snow upon the tops of high mountains, which are nearer than the level portions of the earth to the sun? Because they only heat those bodies which can absorb their warmth, as the rough surface of the earth. The snow is indeed struck by the rays of the sun, but being a white and shining body it reflects them and remains cold.

44. *Formation of Dew.* — When the surface of the earth has become warm, the air is heated by it; hence, during the day the lower strata will always be warmer than the upper. But a change takes place after the sun has gone down. The earth continues to radiate heat without receiving any in exchange, and its temperature consequently diminishes. Neither does the air so readily part with its heat, and therefore it attains during the night a higher temperature than the surface of the earth; it is only cooled where it comes in contact with the colder earth. If this cooling should reach the dew-point of the air (§ 38), then the vapors are condensed, on the soil or on vegetation, in the form of

small drops, just as a tumbler is covered with vapor when brought from a cold into a warm room,—dew forms. If the temperature of the earth sinks in the night to the freezing point, or below it, the aqueous vapor is deposited in a solid form, and is called *frost*.

The radiation of heat from the earth is greatest when the weather is clear and serene; but it is obstructed by clouds and wind. Thus the most copious deposit of dew takes place only in clear and quiet nights. The clouds serve as a screen in reflecting back to the earth the rays of heat, so that it can only cool gradually. The same effect is produced by the mats, straw, and boards with which the gardener covers his young plants to protect them from the late frosts of spring, or from freezing. The annexed figure, in which arrows denote the direction of heat, will serve to render this process more intelligible.

Fig. 20.



SOLUTION AND CRYSTALLIZATION.

45. *Solution.*—Water can dissolve many bodies, and unite intimately with them, without losing its transpar-

ency. Such combinations are called solutions. If rain-water meets with soluble substances, either in the earth or in the rocks through which it oozes, it dissolves them; and this explains why almost all spring-water, as it evaporates, yields an earthy or saline residue. Frequently this residue, particularly when it contains lime, is so altered during evaporation, that it can no longer be dissolved in water, and forms a hard incrustation round the inner sides of the vessels used in cookery. The springs of Carlsbad deposit so much residue, that articles immersed in them appear in a short time to be externally petrified or incrusted. If water is unusually rich in soluble substances, especially such as possess medicinal properties, as, for example, iron, sulphur, &c., it receives the name of *mineral water*, and the springs from which it issues are called mineral springs. A pound of sea-water contains about half an ounce of substances in solution.

46. *Experiment.* — Pour a teaspoonful of slaked lime (§ 33) into a bottle, and fill it with water, cork it up, and, after shaking it for some minutes, let it stand until the water has become perfectly clear. By carefully inclining the bottle, most of the liquid may be poured off free from the sediment. This operation is called *decantation*, and the clear liquid is *lime-water*. Lime is but slightly soluble in water, three hundred ounces of water being required to dissolve half an ounce of lime; the excess remains undissolved, and as lime is heavier than water, it settles at the bottom. That a portion of it has been dissolved is known by the peculiar taste imparted to the liquid. This taste is called *alkaline*.

Keep a part of the lime-water in a well-stopped bottle for future use; it will remain transparent and clear. Pour the remainder into a tumbler, and expose it to the air; the water soon becomes turbid and covered with a film, which gradually grows thicker, and settles at the bottom. If after some days the water has become clear again, it will have lost its alkaline taste; the lime dissolved in it, having been chemically changed by the air and rendered insoluble, will be found as a powder at the bottom of the tumbler.

Fig. 21.

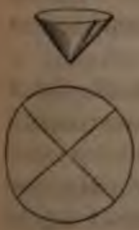
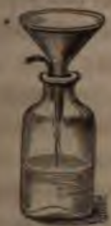


Fig. 22.



47. *Experiment.* — Put into a flask half an ounce of litmus, pour over it three ounces of water, and let it remain in a warm place until the liquid has obtained a dark-blue color. Litmus consists of a blue coloring-matter, which is soluble in water, and is hence taken up by it; it also contains some earthy matter, which is insoluble, and is deposited as a slimy mass. These two substances might be separated from each other, as in the former experiment, by decantation, but it can be done more readily by *filtration.* For this purpose, cut a piece of blotting-paper into a circular shape, fold it together twice, and then place this filter into a glass funnel. That the paper and the glass may not come into too close contact, place between them thin pieces of wood or glass; a piece of cord must also be inserted between the funnel and the neck of the flask into which the liquid is to be filtered, to allow an opening for the escape of the air from the flask, as otherwise the fluid could not flow in. The filter, which must never be higher than the top of the funnel, is first moistened with water before the fluid is poured upon it. Blotting-paper consists of fine linen or cotton fibres matted together, between which are

small interstices or pores, through which liquids, but no fine solid particles, can pass; these remain on the filter. Writing-paper cannot be used for filtration, as its pores are filled up by glue or starch.

48. *Experiment.* — Pour a part of the obtained solution into a saucer, and pass strips of fine blotting or of letter paper one or more times through it, until they have acquired a distinct blue color. Preserve these strips, after being dried, in a box; they are called blue litmus or test-paper; they are reddened by vinegar, lemon-juice, and all acid fluids, and serve to test a liquid, to ascertain whether it is *acid* (has an acid reaction).

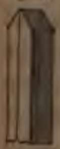
Experiment. — Mix cautiously another portion of the solution with lemon-juice, until the blue color appears distinctly red; this also serves to color paper. The red test-paper is used for the purpose of recognizing a class of substances opposed to acids, that is, alkaline or basic bodies; these restore the original blue color of the paper, as can be seen by bringing it into contact with lime-water or moistened ashes.

49. *Experiment.* — Add gradually, with constant agitation, to one ounce of cold water, powdered saltpetre, as long as it continues to be dissolved, perhaps about a quarter of an ounce; if more is added than is necessary, it will remain undissolved at the bottom of the vessel. This solution is said to be *saturated in the cold.* If this mixture be boiled, and saltpetre again be added, then about two ounces more will be required to saturate the water. A thermometer held in this *boiling saturated* solution will indicate about 108° C., while simple boiling water indicates only 100° C. *All saline solutions boil and freeze with more difficulty than water.* All bodies soluble in water behave in a similar man-

ner; that is, they are soluble in it only in fixed quantities, and in most cases hot water dissolves more of them than cold.

50. *Experiment.* — If the solution obtained in the last experiment be poured into a porcelain dish, previously heated, and be suffered to remain quiet until cold, then the two ounces of saltpetre which were last added separate again, not as powder, but as regularly formed prisms. These prisms are six-sided, and are surmounted by two faces similar to a roof; they are called *crystals of saltpetre.* (Fig. 23.) All crystals are characterized by having planes, edges, and angles, constructed, as it were, of simple triangular, quadrangular, or polyangular pieces, artificially polished; this symmetry is found even in the interior of them, as can easily be seen by holding a piece of transparent crystal towards the light, and turning it slowly round; or breaking it, when the fragments will often exhibit the same regular form which characterized the whole crystal. Thus in inanimate nature a mysterious power exists, similar to that which compels the bees to construct their six-cornered cells, and the potato to produce its five-angled corolla and five stamens, and by which the smallest particles of bodies, called *atoms*, are forced to arrange themselves in a fixed order, assuming a regular shape. But this can only be accomplished by a body in its fluid or aeriform state, since a *free motion* of the atoms is essential. Time also is required for this operation; hence crystals are always more regular the more slowly they are formed. Many of the splendid crystals which have been dug from the depths of the earth were, perhaps, thousands of years in forming.

Fig. 23.



51. *Experiment.* — Evaporate the mother-liquor of

the former experiment, at a gentle heat, until scales are formed on the surface, then remove it from the fire, and let the liquid cool, *stirring constantly* with a wooden stick. In this way, instead of crystals, a *powder of saltpetre* will be obtained.

The mother-liquor, just alluded to, may be regarded as a cold saturated solution, containing about a quarter of an ounce of saltpetre. If by evaporation only so much water is left as is sufficient when hot to keep in solution but a quarter of an ounce of saltpetre, then crystals begin to appear in the form of a film on the colder parts, indicating the saturation of the liquid. If this again is allowed to cool quietly, a second crop of crystals would be obtained; but by continual stirring they are broken at the moment of their formation, — by slow movement into a coarse, and by rapid movement into a fine powder. This may be called *interrupted crystallization.* Sugar presents a similar example; the same syrup, when cooled quietly, yields rock-candy; if stirred, it yields common loaf-sugar.

52. *Experiment.* — Put into boiling water as much common salt as will dissolve, and let the solution cool; no crystals will form, because salt is as soluble in cold as in hot water. Now evaporate one half of the solution over a spirit-lamp, and set aside the other half in a warm place; in the first case, mere irregular grains of salt will be obtained, but in the latter case, after some days, regular cubes of salt will be deposited.

53. *Experiment.* — Dissolve a spoonful of salt and one of saltpetre in lukewarm water, and put the solution in a warm place, that the water may gradually evaporate; the two salts, which are intimately united in the solution, will upon crystallization separate completely from each other. The saltpetre separates into long prisms,

containing no trace of the common salt, and the latter separates into cubes, entirely free from saltpetre. Thus the particles of salt and saltpetre did not attract each other; but upon crystallizing out of the solution, the *homogeneous* salts assumed separately a regular form, precisely as if one only of these two substances had been dissolved.

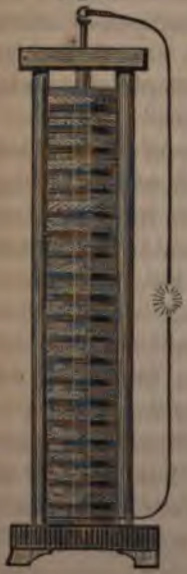
54. In our climate, water takes a solid form during the winter only, and it is well known that, as snow or ice, it often forms the most regular crystals. But it also exists in a solid form in many bodies where we should not expect to find it; one pound of iron-rust, for example, contains nearly three ounces, and one pound of slaked lime four ounces, of water, and yet both are apparently dry. This water is said to be *chemically combined.* It also unites with other solid bodies, for which it has an affinity. Such combinations of solids with water are called *hydrates.* It is also frequently present in salts, as can be shown in a simple manner in the case of the well-known Glauber salts.

Experiment.—Place half an ounce of crystallized Glauber salts in a warm place, when it will soon lose its transparency, and finally crumble into a white powder, weighing hardly a quarter of an ounce. That which has been lost was water, and it is evident that it was this water which gave to the salt its crystalline form and transparency, these both vanishing with the escape of the water. For this reason the water, on which depends the crystalline form of many salts, is called the *water of crystallization.* Saltpetre and common salt, treated like Glauber salts, lose nothing in weight, neither do they become opaque nor pulverulent; they contain no chemically combined water.

COMPOSITION OF WATER.

55. Besides that electricity, which we admire on a grand scale in the majestic phenomena of lightning, or which we generate on a small scale by rubbing various bodies together, a second kind of electricity is also recognized, which is called galvanic force, or *galvanism*. This has attained great importance in chemistry, as by means of it the chemist is enabled to decompose almost all chemical combinations, even into their component parts or chemical elements. By galvanic force water can easily be decomposed into its elementary parts. This sort of electricity may be generated in various ways; it is developed in every chemical combination or decomposition, indeed quite frequently when heterogeneous substances, whether solid, liquid, or aeriform, are brought into contact. The oldest and most common galvanic apparatus is the *voltaic pile*, in which electricity is excited by the contact of two different metals, commonly zinc and copper. A copper plate placed upon one of zinc is called a pair of plates; many such pairs are laid, one above the other, each pair being separated by a piece of cloth moistened with salt water. The relative position of the metals in each pair must be observed throughout the whole series, so that, if the pile commences with a zinc plate, it shall terminate with a copper one. These two extremities are

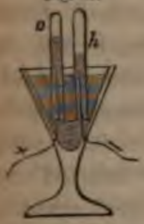
Fig. 24.



called the poles. Zinc is called the + pole, and copper the — pole; they are provided with metallic wires, that the electric or galvanic stream which is excited in the pile may be conveyed to any place desired. When the two ends of the wires are brought very near to each other, sparks are seen to dart from one to the other; this is a token of the galvanic current, manifesting itself in the same manner as the current of the electrical machine.

To decompose water by means of this pile, the two wires, being previously tipped with platinum, are conducted into a vessel of water, and two test-tubes, filled with water, are inverted, one over the end of each wire; there are evolved from the ends of both wires small bubbles of air, which ascend into the test-tubes, gradually displacing the water from them. From the + or zinc wire, only half as much gas is generated as from the other; consequently the tube connected with the zinc will only be half emptied by the time the water from the other is entirely expelled, and a glowing shaving introduced into it will burst into a brilliant flame; it is called *oxygen gas* (*O*). The gas evolved from the — or copper end, on the contrary, extinguishes this shaving; but the gas will burn spontaneously if kindled by the flame of a lamp, held over it;—it is called *hydrogen gas* (*H*). These are the component parts of water; it consists of one measure (volume) of oxygen, and of two measures of hydrogen. From one measure of water, when decomposed into its elements, several thousand measures of these two gases may be obtained.

Fig. 25.



NON-METALLIC ELEMENTS, OR METALLOIDS.

FIRST GROUP: ORGANOGENS.

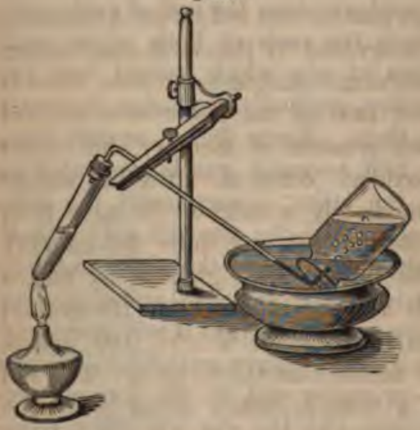
OXYGEN (O).

At. Wt. = 100. — Sp. Gr. = 1.1.

56. Oxygen may be obtained in great quantities from water, by means of the galvanic battery; but in a more simple manner as follows.

Experiment. — Introduce into a somewhat tall, but not too thin, test-tube, 109 grains of red oxide of mercury. One end of a bent glass tube is adapted to it by means of a perforated cork, and the other end is conducted into a vessel filled with water. Either suspend the tube by means of a piece of cord or wire, or support it by a retort-holder. A retort-holder is a wooden stand provided with a movable vice, by which glass vessels can be held in the most convenient manner, as shown in the annexed figure. Then heat the test-tube until all the oxide of mercury has disappeared. The red powder becomes black as the heat increases, and bubbles of air escape, which are collected in a glass bottle held over the end

Fig. 26.

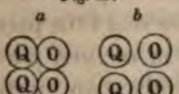


of the tube, this bottle having been previously filled with water and then inverted into the bowl, after closing the mouth of it with the finger or a glass plate. No water will escape until bubbles of air from the tube are passed into it, which, on account of their greater levity, ascend and displace the water. When the water is displaced, remove the bottle and close it with a cork, replacing it with another bottle, likewise previously filled with water, and repeat this process until the evolution of gas ceases. The first bubbles that pass over consist of atmospheric air contained in the test-tube, but the *oxygen gas* quickly succeeds. This is *one* of the component parts of the red oxide of mercury, and can easily be recognized by the vivid combustion in it of a glowing shaving. At the same time there is formed on the upper part of the test-tube a brilliant metallic mirror, which consists of mercury, the *second* element of the red oxide. When the latter has entirely disappeared, immediately withdraw the tube from the water, let the test-tube cool, and unite the mercury adhering to its walls into a single globule, by means of a feather. It will amount in weight to 101 grains; this, subtracted from the original weight, 109 grains, leaves 8 grains, the amount of the oxygen. The red powder consists of a brilliant heavy metal and of a gas, two entirely dissimilar bodies. If these are chemically combined together by proper means, they will unite again to a red oxide, a body in which the peculiar properties of mercury as well as of oxygen are entirely lost.

57. This experiment shows, also, how the force of heat alone can destroy a chemical combination, or in other words the affinity of two bodies for each other. This can be explained as follows. Chemical affinity

acts only at *imperceptible distances*, consequently only when bodies are in closest contact; heat counteracts this power, for it exerts an expansive action, and consequently separates the constituent particles from each other. In the cold, or at ordinary temperatures, the single particles of the quicksilver (Q) and oxygen (O) are so closely united, that chemical force is sufficient to hold them together (*a*, Fig. 27); but at an increased temperature they are so far separated (*b*), that the influence of chemical attraction is overcome. This occurs so much the more readily in this instance, as both the quicksilver and oxygen, having, when heated, a strong tendency to become aeriform, help likewise to counteract the chemical force.

Fig. 27.



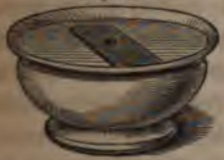
58. The bottles containing the oxygen appear to be empty, for oxygen is as colorless and invisible as common air, and is without odor or taste. In German it is called *Sauerstoffluft*, signifying sour gas.

Experiment. — Introduce a glowing shaving into a bottle of oxygen; it will kindle and burn for some time with great brilliancy and a very dazzling flame, and then be extinguished. The same takes place when a piece of lighted tinder is affixed to a wire and suspended in the oxygen; the tinder burns with a lively flame, while, as is well known, it merely smoulders away in the open air. Oxygen possesses, at a high temperature, a strong affinity for the component parts of wood and tinder; that is, it combines with them with great energy, and consequently with the development of heat and light. When the combination has ended, and the oxygen is consumed, the combustion ceases. The product of the combustion, that is, the combination of the wood with the oxygen, is also aeriform; but burning substances are extinguished in the newly formed gas. If the bottle be rapidly whirled round, the gas formed by the combustion will escape, and atmospheric air will supply its place. Air contains free oxygen; and a kindled shaving will burn in it for some time, but far slower and less briskly than in pure oxygen; because common air contains only one fifth part of oxygen. Accordingly, a combustion in oxygen proceeds five times more rapidly and violently than in atmospheric air.

59. *Experiment.* — To prepare a larger quantity of oxygen, take one hundred grains of *chlorate of potassa*, and heat it in the same manner as described in the former experiment; the salt will soon melt, and afterwards boil. As soon as the boiling commences, the flame must be diminished, to prevent the mass from foaming over. When the liquid thickens, if some of the substance should be found adherent to the colder parts of the test-tube, approach it with the flame of the lamp, until it is again melted down. As soon as the gas ceases to be generated, draw the tube *immediately* from the water.

60. For collecting gases in larger quantities, the following contrivance may be resorted to. Make a shelf out of slate or a piece of lead, some inches broad, and so long that it will rest about half way up the sloping walls of the vessel in which it is to be placed; bore a small hole through the centre of the shelf with some appropriate instrument. When wanted for use, pour into the vessel as much water as will be sufficient to cover the shelf

Fig. 28.



an inch deep, and then invert the vessel intended for the reception of the gas, with its mouth exactly over the opening, placing the extremity of the glass tube, from which the gas proceeds, directly beneath, so that the gas may enter it as through a funnel. This contrivance is called a *pneumatic trough.* In order to collect and preserve larger quantities of gas, and to experiment with them more conveniently, special contrivances, called *gasometers*, are used in chemical laboratories.

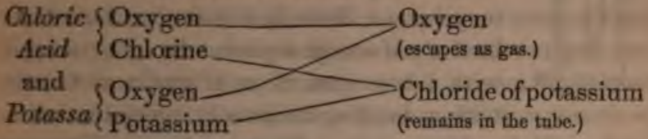
61. Chlorate of potassa contains for every one hundred grains about forty grains of oxygen chemically combined; by the application of heat, these become free and escape. Red oxide of mercury contains only eight per cent. of oxygen; therefore the former will yield five times more oxygen than the latter. If vials of twelve ounces' capacity are selected for receiving the gas, we shall be able to fill five of them, and shall have in each about eight grains, or nearly twenty cubic inches, of oxygen.

Chlorate of potassa may, under some circumstances, as when strongly rubbed, or treated with sulphuric acid, occasion *very dangerous explosions;* but no danger is to be apprehended from the application of it, when made as above directed.

62. *Experiment.* — Add warm water to the salt remaining in the test-tube after the expulsion of the oxygen, and place the tube in a warm place until the salt is dissolved; evaporate the solution gradually, over a stove, when small cubic crystals (chloride of potassium) will be deposited. The chlorate of potassa crystallizes in thin tables or plates, the heated mass in cubes; this difference in the form of the crystals alone *indicates that,* by the heating of the former, an entirely

new salt is formed, and one, indeed, which no longer contains oxygen. The following diagram will illustrate this more clearly.

Chlorate of potassa consists of

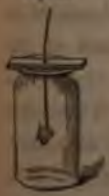


Experiments with Oxygen.

63. *Experiment a.* — Fasten a piece of charcoal to a wire, and kindle it in the flame of a lamp, and then introduce it into a bottle of oxygen; it will burn very vividly, and with a flame. If a piece of moistened blue litmus-paper (§ 48) be introduced into the bottle, after the combustion, it will be reddened; consequently an acid gas has been formed from the charcoal and the oxygen; it is called *carbonic acid*. Close the flask, shake it a few times, and place it aside.

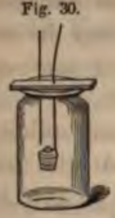
64. *Experiment b.* — If some pieces of sulphur are fastened to a longer wire, kindled and suspended in a second bottle, they will burn with a beautiful blue flame. The gas formed from this union of sulphur and oxygen has a very irritating odor; it likewise turns litmus-paper red, and consequently it is of an acid nature. It is called *sulphurous acid*. This bottle is also closed and preserved for future use.

Fig. 22.



65. *Experiment c.* — Take a small piece of phosphorus, which, on account of its inflammability, must be cut off under water from the stick, and place it, after having been *well dried* between blotting-paper,

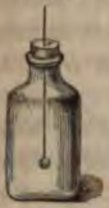
Fig. 30.



in a scooped-out piece of chalk. Fasten the latter to a wire, and introduce it into a third flask of oxygen. Affix the wire to a transverse piece of wood, so that the chalk may hang a little below the centre of the bottle. If the phosphorus be now touched with a hot wire, it will kindle and burn with a dazzling brilliancy, filling the bottle with a thick white smoke. This smoke consists of a chemical combination of oxygen and phosphorus; it reddens the blue test-paper, consequently is also an *acid;* it is called *phosphoric acid.* If the bottle be allowed to stand for a time, the smoke will sink to the bottom, and dissolve in the water previously put there, which thus acquires an acid taste.

66. In the same way as the tasteless coal and sulphur and the phosphorus acquire, by combination with oxygen, acid properties, so many other simple bodies are converted by oxygen into *acids;* this is the reason why it has received the name *oxygen*, derived from two Greek words, one of which signifies *acid*, and the other *to generate.* Thence the words *oxidate* and *oxide*, so frequently occurring in chemistry. *Oxidate* signifies to unite with oxygen, to burn; *oxide* is the product of the combination, and signifies a burnt substance, that is, a substance combined with oxygen. The acids just alluded to may also be called *acid oxides.*

Fig. 31.



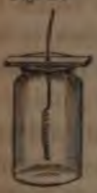
67. *Experiment d.* — Fix securely to a wire a piece of sodium, and let it remain for some hours in a bottle filled with oxygen; it becomes converted into a white mass, which easily dissolves in water. The solution obtained has an alkaline taste, similar to lime-water; the color of blue

test-paper is not changed by it, but it turns red test-paper *blue;* this is a combination which may be regarded as the opposite of acids; it is called *oxide of sodium.* Let this also be kept for future use.

The metal *sodium* has such an extraordinary affinity for oxygen, that it quickly attracts it from the air. Therefore, to preserve it unchanged, it must be kept in some liquid containing no oxygen; as, for instance, in naphtha or petroleum.

68. *Experiment e.*— A piece of fine iron wire is so wound round a slate or common lead pencil, that, on the withdrawal of the latter, the wire may have a spiral form. Fasten the upper part of this wire, as in experiment *c*, to a cross-piece of wood, and place on the lower end of it a small portion of tinder. When this is kindled, introduce the wire into the oxygen; the burning tinder heats the iron to redness, which then burns brilliantly, throwing out sparks. The iron, when red-hot, combines with the oxygen. The burnt or oxidized iron (iron scales) melts, and falls to the bottom in globules, which are so hot that they are liable to melt into the glass, though it be partly filled with water. This heat, as in the preceding case, is the result of chemical combination taking place. Oxide of iron is insoluble in water, and for this reason it affects the color neither of the blue nor of the red test-paper; if it were soluble, it would, like oxide of sodium, convert the red into blue paper.

Fig. 22.



69. Such combinations of oxygen as are not acid, but agree in their properties with the oxide of sodium or of iron, are called *bases* or *basic oxides.* Most of the combinations of the *metals* with oxygen belong to the bases.

70. By the foregoing experiments on oxidation, the question recurs, — How much carbon, sulphur, &c., have the eight grains of oxygen contained in each bottle consumed or taken up? The reply is, — They have taken up different quantities.

They have united as follows: —

8	grs.	of oxygen	with	3	grs. of	carbon,	forming	11	grs. of	carbonic acid.
8	“	“	“	8	“	sulphur,	“	16	“	sulphurous acid.
8	“	“	“	6½	“	phosphorus,	“	14½	“	phosphoric acid.
8	“	“	“	23	“	sodium,	“	31	“	oxide of sodium.
8	“	“	“	20	“	iron,	“	28	“	black oxide of iron.
8	“	“	“	1	“	hydrogen,	“	9	“	oxide of hydrogen (water).

Carbonic acid may be prepared in different ways, but it is always so constituted as to contain eight grains of oxygen united with three grains of carbon, and this same regularity exists in all the above compounds, as indeed in all chemical combinations. It is a law of nature; *chemical combinations always take place according to certain fixed proportions by measure or weight.* This doctrine is called Stochiometry (from στοιχεῖον, element, and μέτρον, measure).

71. *Experiment.* — The liquid in the vessel *c* reddened blue test-paper, and had a sour taste; the liquid in the vessel *d*, on the contrary, turned the red paper blue, and had an alkaline taste. Add the latter slowly, and at last only by drops, to the former, testing the mixture frequently with a strip of blue and of red test paper; there will be a point when the color of these two papers will no longer be changed. The acid and alkaline tastes have likewise disappeared, and the mixture has acquired a slightly saline taste; it is *neutral.* The phosphoric acid has chemically combined with the oxide of sodium, forming a new body having no similarity to either of the substances of which it was

composed. To obtain a better knowledge of it, let the liquid remain in a warm place until the water has evaporated, when small crystals will be deposited. Such a combination, consisting of an acid and a base, is called a *salt*. This salt, phosphate of soda, is called *soluble*, because it assumes a liquid form upon the addition of water.

72. *Experiment.* — Pour into the bottle which contained the carbonic acid gas (experiment 63), some lime-water (§ 46), and agitate it; the liquid will become milky, and after standing, a white powder will subside. The lime in the lime-water is a base, as well as the oxide of sodium; the lime combines with carbonic acid, they mutually neutralizing each other; but the salt which is formed (carbonate of lime or artificial chalk) is *insoluble* in water, and hence separates from it. That the carbonic acid here disappears, and is condensed into a solid body, is indicated by the suction exerted upon the finger with which the mouth of the bottle was closed during the shaking, and the rushing in of air after its removal.

73. *Experiment.* — Quite the same thing occurs, when lime-water is poured into the bottle of experiment 64; the irritating odor of the sulphurous acid contained in it vanishes, owing to its combining with the lime. The salt formed (sulphite of lime) is *difficultly soluble* in water.

74. *Experiment.* — Pour gradually into the bottle of experiment 68, one dram of common sulphuric acid. It heats on uniting with the water; and, after repose and frequent agitation, the red oxide of iron which collects on the sides of the vessel, as well as the black oxide of iron at the bottom, will dissolve. In this case, also, a salt is formed, since the base (oxide of

iron) has united chemically with the acid; the yellowish liquid holds the *iron salt* in solution.

75. *Degrees of Oxidation.*— Oxygen is a universal food for all elements; it is consumed by them, and, as already stated, in fixed quantities. But the appetite of an element for oxygen often varies according to the circumstances under which the latter is presented to it; for example, it is greater under the influence of heat than of cold, greater where there is an excess than where there is a deficiency of oxygen. Hence many elements frequently consume greater quantities of it at a high than at a low temperature, and when the supply is copious than when it is deficient; and this excess or diminution of consumption is likewise prescribed by fixed laws. The different proportions in which substances unite with oxygen are called its *degrees of oxidation.*

76. When sulphur is burnt in oxygen gas or in the air, it combines with oxygen, forming *sulphurous acid;* but it can be made to unite with one half as much more oxygen, and then *sulphuric acid* is formed.

When phosphorus is rapidly burnt, it forms with oxygen *phosphoric acid;* but if it be exposed to the air without the application of heat, or be burnt with imperfect access of air, then *phosphorous* acid is principally formed, which contains two fifths less oxygen than phosphoric acid.

Accordingly, by the terms sulphur*ic* and phosphor*ic* acids, are to be understood combinations with *more* oxygen; by the terms sulphur*ous* and phosphor*ous* acids, combinations with *less* oxygen. If an element yields more than two acids with oxygen, then new names are formed by prefixing to the acids the terms *per* or *hypo;* for instance, perchloric acid, hyposulphuric and hyposulphurous acids, &c.

77. Besides the red oxide or peroxide of quicksilver (§ 56) there is yet another combination of quicksilver with oxygen, which is black, and contains only half as much oxygen as the former; it is called the protoxide of quicksilver. Iron also forms two combinations with oxygen; one of a reddish-brown color (sesquioxide of iron), and the other of a black color, containing one third less oxygen (protoxide of iron). Accordingly a *peroxide* or a *sesquioxide* is the combination of a metal with a greater quantity of oxygen, and a *protoxide* is a combination with a less quantity of oxygen. Many metals have the power of uniting in more than these two proportions with oxygen; in this case, the combination with a less quantity of oxygen than in the protoxide is called *suboxide*, but that with more oxygen than in the per- or sesqui-oxide, is called *hyperoxide*. Neither the lower nor the higher oxides act as bases, that is, they will not unite directly with acids to form salts; but, nevertheless, this may happen when the suboxide receives so much oxygen, or the hyperoxide parts with so much, as to form, in either case, per- or sesquioxides or protoxides. Some metals in their highest state of oxidation possess no longer basic properties, but, on the contrary, acid properties (*metallic acids*).

78. If we compare the different quantities of oxygen which one and the same body can take up, they will always be found in very simple proportions; for instance: —

In sulphurous and sulphuric acids,	as 2 to 3.
" phosphorous and phosphoric acids,	" 3 to 5.
" protoxide and peroxide of mercury,	" 1 to 2.
" protoxide and sesquioxide of iron,	" 2 to 3.

A similar regularity exists in all other chemical combinations.

79. The *hyperoxides* easily give up a part of their oxygen, either when heated alone or with certain acids; hence they can be made use of for obtaining oxygen. An oxide of frequent occurrence in nature is the *hyperoxide of manganese*, used for coloring potters' ware brown. It is a combination of the metal manganese with oxygen. Oxygen is usually obtained from this when wanted in large quantities, as it can be put in an iron vessel and heated to a bright redness. If the manganese is heated alone, one third of the oxygen contained in it is obtained, and red oxide of manganese remains behind; but if heated with the addition of sulphuric acid, one half of its oxygen is obtained, and the remainder is protoxide of manganese, which combines with the sulphuric acid, forming a salt.

80. Oxygen is absolutely necessary to all living creatures. All the air which we breathe must contain free oxygen; if this is wanting, suffocation is induced. The chemists who discovered it seventy years ago, and first prepared it pure, gave to it, for this reason, the name of *vital air*. In later times it was designated *empyreal air*, because it was found that every combustion, however familiar to us, was a process of oxidation, in which the oxygen of the air combined with the particles of the burning material. The symbol for oxygen is O, the *first letter* of oxygen. It has been agreed to express simple bodies by the first letters of their Latin names.

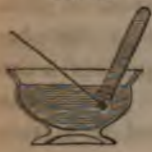
HYDROGEN (H).

At. Wt. = 12 5. — Sp. Gr. = 0.068.

81. *Experiment.* — Boil some water for fifteen minutes, that all the air contained in it may be expelled; let

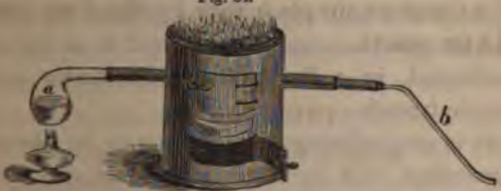
it cool, and fill a bowl and a test-tube with it; close the latter with the finger, and invert it under the water in the bowl. Now secure to a wire a piece of sodium, of the size of a lentil, and thrust it quickly under the opening of the test-tube; the metal frees itself from the wire, and, as it is lighter than water, it ascends into the tube, floating there with a circuitous motion; a gas is evolved from the water, which in a few moments becomes displaced by the gas from the tube. This kind of gas is the second element of water, and is called *hydrogen*. The experiment in § 67 demonstrates that sodium has a very great affinity for oxygen, and this affinity is so strong, that the sodium removes from the water its oxygen, whereby the hydrogen is liberated. Close the tube again with the finger, remove the tube from the vessel, and hold a burning taper over it, when the gas will burn with a flame. Hydrogen is a *combustible* gas. If the interior of the moist tube be tested with a strip of red test-paper, this assumes a blue color. The same base, oxide of sodium, has been formed as when the sodium was exposed to oxygen or to the air. It is dissolved by the water.

Fig. 33.



82. What sodium accomplishes at ordinary temperatures, iron cannot do until it is heated to redness.

Fig. 34.

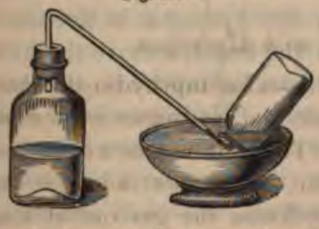


Pass water in the form of steam, obtained by boiling the water in the retort, *a* (Fig. 34), through a red-hot iron pipe containing a spiral wire; for instance, a gun-barrel. At this high temperature the iron in the pipe unites with the oxygen in the water, forming black oxide of iron, and the hydrogen is set free. This is the method by which the celebrated French chemist, Lavoisier, sixty years ago, proved that water is not a simple body, but consists of two gases, oxygen and hydrogen.

83. The decomposition of water by iron is more easily effected through the presence of an ally, which supports the iron in its endeavour to extricate the oxygen from the water. Such an ally is sulphuric acid.

Experiment. — Put a quarter of an ounce of wrought-iron filings into a flask, and pour over them two and a half ounces of water. No action takes place, but if half an ounce of common sulphuric acid be gradually added, at the same time keeping the flask in constant motion, ebullition and heating of the liquid will immediately ensue. The ebullition is caused by the evolution of a species of gas, hydrogen. Insert into the opening of the flask a perforated cork, to which is fitted a bent glass tube. Allow the first portions of the gas to escape, then collect it, as the oxygen was collected, in a flask filled with water over the pneumatic trough.

Fig. 35.



There is one indispensable caution to be observed in experimenting with hydrogen, which is, *not to admit the gas into the receiver until all the atmospheric air existing in the flask has been expelled*, as otherwise an explosion might take place.

84. *Experiment.* — If sulphuric acid is poured into water, considerable heat is evolved; but this heat is much stronger when the water is poured into the sulphuric acid. The mixture is best made in the following manner. Pour two and a half ounces of water into a sufficiently large stone jar, which is placed in a bowl filled with water; now weigh in a flask half an ounce of common sulphuric acid, pour this in a small stream into the water, stirring the water continuously with a glass or porcelain rod, and let the jar remain in the bowl until it is entirely cold. This mixture is called *diluted sulphuric acid;* the strong acid, on the contrary, is called *concentrated sulphuric acid.*

Fig. 36.

85. *Experiments with Hydrogen.*

Experiment a. — Inflame hydrogen contained in a flask, and immediately pour in some water. The water does not extinguish the flame, but rather increases it, since it rapidly forces the gas out of the flask. The gas does not burn in the interior of the vessel, but only on the outside, where it is surrounded by atmospheric air.

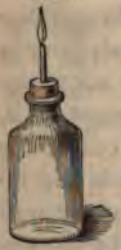
Fig. 37.

Experiment b. — Hold an empty tumbler over a flask of hydrogen for some minutes, then quickly invert the former, and apply to it a lighted taper, when a flame will burst forth from the tumbler with a whizzing noise. The gas has ascended from the flask into the tumbler, and is consequently *lighter* than common air. In this experiment the lower vessel must not be immediately exposed to the lighted taper, *because, if* all the hydrogen is not displaced, an explosion might ensue that would break the flask; but if the taper be applied after ten minutes have elapsed, the flask will be found no longer to contain any combustible gas, this having entirely escaped.

Hydrogen is the *lightest* of all gases; $14\frac{1}{2}$ measures of it weigh only as much as one measure of atmospheric air. On account of its levity, it is used for filling balloons.

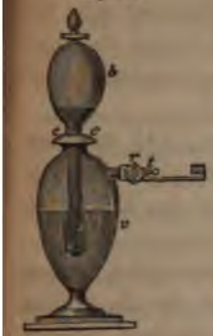
Experiment c.—If, instead of the glass tube, a piece of pipe-stem be adapted to the cork of the flask from which hydrogen was evolved, and the gas then lighted, it will burn like a taper. To kindle the gas, instead of a match or a taper, very finely divided platinum may be employed. This can be prepared in a few minutes by dropping a solution of platinum on blotting-paper, attaching it to a wire, and igniting it over a spirit-lamp, till nothing but a gray coherent ash remains. The platinum is thus reduced to an extremely minute state of subdivision, and in this state it exhibits the remarkable property of igniting in hydrogen and inflaming it. It is called spongy platinum, and is employed as tinder in the well-known *Döbereiner's inflammable lamp.*

Fig. 38.



The apparatus here represented consists of a syphon, *b* (Fig. 39), fitted perfectly air-tight at *c* into the lower vessel, *v*; the lower part of the syphon is encompassed by a cylinder of zinc. If diluted sulphuric acid is now poured in, hydrogen is evolved, the pressure of which forces back the liquid into the vessel *b*, until the piece of zinc is no longer in contact with the liquid. Upon opening the stop-cock, *r*, the gas issues from the fine jet, *t*, and is directed against the spongy platinum. As the

Fig. 39.



gas escapes, the sulphuric acid descends again into the lower vessel, and generates fresh hydrogen upon reaching the zinc. Spongy platinum possesses, in a high degree, the power of absorbing oxygen and condensing it within its pores; if hydrogen be then presented to it, these two gases will be brought into such intimate contact, by the powerful force of attraction, that they will chemically combine to form water, and the heat thus liberated is sufficient to ignite the platinum tinder, and to inflame the gas, which subsequently issues from the jet. Many aeriform bodies, which do not freely unite with each other, can be forced to combine by means of spongy platinum.

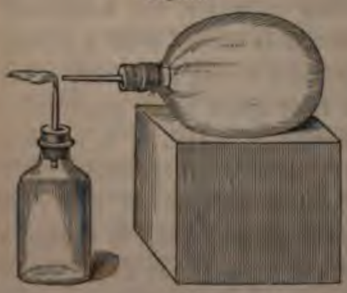
86. *Explosive Gas.* — The extraordinary degree of heat developed by the chemical union of oxygen and hydrogen may be shown by the following experiments. Insert into the opening of a large pig's bladder, which has been softened by soaking in water, the broken-off neck of a flask, and bind it firmly round with a string. Then select two perforated corks, fitting this neck. One cork is connected with a bent glass tube, conducting the oxygen from the apparatus in which it is evolved (§ 59) into the bladder, which soon becomes filled with it. When this operation is finished, replace the first cork by the second, having a glass tube adapted to it only a few inches long and drawn out to a point at its outer end, and provided with a wax stopple pressed upon the opening. A glass tube may be formed into a point by heating it in the flame of a spirit-lamp, constantly turning it round at the same time, till it becomes so soft

at the desired place, as to be easily drawn out. Break it at the slender part, and hold it in the flame for some moments, until the sharp edges are rounded off by incipient melting. It would be more convenient, though somewhat more expensive, to substitute for the above contrivance a jet provided with a small brass stop-cock.

Fig. 40.

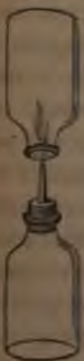
The bladder thus arranged and filled with oxygen is now placed on blocks, at such a height that the point of the glass tube shall be on a level with the hydrogen flame, produced as explained in a former experiment. Press upon the bladder with the hand, and the oxygen will escape, blowing into the hydrogen flame, which then takes a horizontal direction. This flame has but little brilliancy, less than the hydrogen flame alone, notwithstanding which it affords the greatest heat yet known. Hold in it a platinum wire, a metal which has never yet been melted in the hottest furnace, and it will melt like wax; hold in it a piece of chalk scraped to a fine point, and it will emit light (sidereal light) of the most dazzling splendor. A watch-spring or a fine iron wire burns in it, throwing out sparks as in oxygen. (§ 68.) But what is the cause of this powerful heat? It is the result of the energetic chemical combination of two substances with each other. *Every chemical combination or decomposition is attended with liberation of heat.*

Fig. 41.



Exact experiments have shown that two measures of hydrogen unite with one measure of oxygen, consequently in just the same quantities as obtained in the decomposition of water by galvanism. (§ 55.) The result of the combination is water. But two measures of hydrogen and one of oxygen do not yield three measures of vapor; they afford two measures only. Thus the two gases condense one third by chemical union. If both the hydrogen and oxygen were suddenly mixed together and then ignited, the whole mass would combine together at once, producing a most violent report, and bursting the vessel to pieces. Such a gaseous mixture is called, for this reason, *explosive gas*. No danger is to be apprehended from the apparatus described, as the explosive gas is formed at the point where the oxygen meets the hydrogen flame, and only in small quantities at once. This apparatus is an oxy-hydrogen blowpipe on a small scale. Hence explosive gas may be regarded as chemically decomposed water, and water as chemically combined explosive gas, or as burnt hydrogen.

Fig. 42.



87. *Experiment.*— That water is really formed during the combustion of oxygen and hydrogen, or when they chemically unite, can easily be shown by inverting a flask over the hydrogen flame; the glass soon becomes clouded over, because the water, which at this heat is generated in the form of steam, condenses in small globules on the cold sides of the glass. By this method one full measure of water has been obtained from one thousand measures of oxygen and two thousand measures of hydrogen.

By the decomposition of water (*analysis*), and by combining together its elements (*synthesis*), it is *proved to consist, in volume*, of one measure of oxygen and two measures of hydrogen, yielding two measures of vapor; in *weight*, of eight parts of oxygen and one part of hydrogen, yielding nine parts in weight of water.

The great difference between the numbers of the measures and those of the weight depends on the fact, that one measure of hydrogen weighs sixteen times less than one of oxygen. On account of the property possessed by hydrogen when combined with oxygen of forming water, the name *Hydrogen* (generating water) has been given to it; its chemical symbol is accordingly H.

88. The *chemical symbols*, which, as previously stated, are derived from the initials of the Latin names of the elements, present not only a very convenient and simple mode of designating the elements, but they represent also their *atomic weights*, which are given at the head of the different sections. Consequently O signifies not merely oxygen, but 100 parts in weight of it (pounds, ounces, grains, &c.); H, not only hydrogen, but also $12\frac{1}{2}$ proportions in weight of it. When two elements are in combination, this is designated by uniting together their symbols; H O, for instance, is the formula for water, and this indicates, not only that water consists of hydrogen and oxygen, but also that it is composed of $12\frac{1}{2}$ parts in weight of hydrogen (1 At. H) and 100 parts of oxygen (1 At. O); or what is the same thing, of 1 part of H and 8 parts of O in weight. In more complex combinations, the different members are separated from each other by a comma, or the sign $+$, as will be seen in the following sections. The smaller numbers in the formula placed *below* the letter modify only the symbol immediately preceding, but the larger numbers *prefixed* to the sign modify all the symbols as far

ıe next comma or + sign. H_2 signifies accordingly atoms of hydrogen, H_3, three atoms, &c.; but 2 H O ates two atoms of hydrogen and two atoms of en, &c. It is earnestly recommended to every be- er in chemistry to familiarize himself with this com- ensive language of symbols.

). The change which iron underwent, when, by the of sulphuric acid, it decomposed water and liberat- he hydrogen, remains now to be considered.

xperiment. — Pour the contents of the flask of ex- ment 83 into a porcelain dish, heat them to boiling, filter them. A black residue will remain on the , which consists of carbon that was contained in iron; the iron itself has been dissolved, and has ed through the filter; it is no longer iron as such, has been converted into a salt of iron, which, on cooling of the solution, is deposited in green, trans- nt crystals. The formation of it is explained in following diagram: —

↗
Water = oxygen and hydrogen
Iron________/ = oxide of iron
Sulphuric acid_________/ = salt of iron.

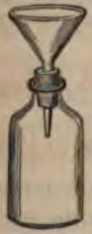
his salt is accordingly called sulphate of iron, com- ly known as green vitriol. Iron and sulphuric acid ıot combine directly with each other, for it is a rule norganic chemistry, with but few exceptions, *that le bodies unite only with simple bodies, and com- d only with compound bodies;* however, this com- tion can take place when the iron is oxidized, and converted into a compound body. The water ains the oxygen requisite for this purpose, but the has not power enough to extricate it without the tance of the sulphuric acid, which, having a strong affinity for a base, coöperates with it and enables i overpower the water, and a base is formed (proto of iron) which immediately unites with the sulph acid. The liberated hydrogen escapes as gas. T sort of affinity is called disposing affinity.

Zinc is frequently used instead of iron in the pr aration of hydrogen.

AIR.

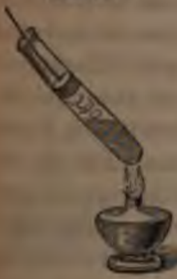
90. The earth is surrounded by air, as by a man it is called the *atmosphere*, and is supposed to ext about forty-five miles above the solid earth. The air p sesses no color, and is transparent; hence it is invisi and its particles are so easily displaced that it can be grasped by the hand. But it is rendered obvi that the air is material, and fills every sp commonly called empty, by wrapping mo ened paper round a funnel, so that it may exactly into the mouth of a flask; if the f nel be now filled with water, the fluid *not* run into the flask, as the air containe the latter will not let it enter; but if the f nel be raised a little, the air escapes, and water immediately rushes into the flask. learn also by the balance that a flask c taining atmospheric air weighs more than it does w the air has been exhausted from it. But air is so li that 800 measures of it weigh only as much as measure of water, yet the atmosphere presses w great weight on the earth and upon every thing th on. But this pressure is only noticed when the ai removed from a place, thus leaving it without coun pressure.

Fig. 43.



91. *Pressure of the Atmosphere.* — *Experiment.* — Wrap some tow round one end of a stick, and grease it with tallow, thus forming a plug, which must be fitted tightly into a strong test-tube. Boil some water in the test-tube, and when the air has been expelled by the steam, causing a vacuum, insert the plug; as the water cools, the plug will be pressed down upon the surface of the water; by heating, it is again forced up by the steam thus generated, and by immersing in cold water it is again forced down. In consequence of the cooling and condensation of the steam a vacuum is formed, and therefore the counter-pressure against the weight of the exterior air is removed; the pressure of the latter, accordingly, forces down the plug. On this principle, the piston is forced up and down in the cylinder of many steam-engines.

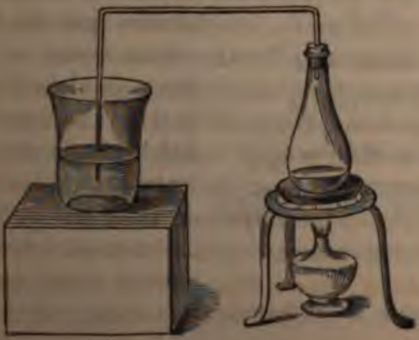
Fig. 44.



92. This pressure often causes the rising and falling of liquids in tubes.

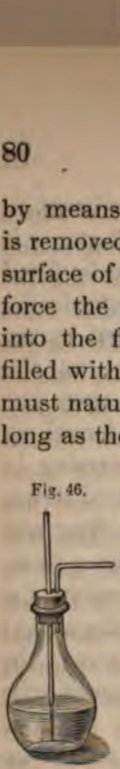
Experiment.—If water is boiled as was directed at §36,

Fig. 45.



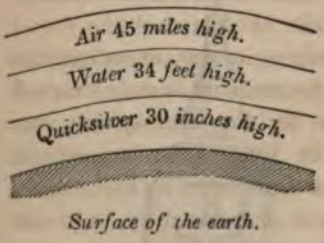
by means of steam, and during the boiling the lamp is removed, then the pressure of the air acting on the surface of the water in the beaker-glass will very soon force the water contained in it through the tube back into the flask, which in a short time becomes quite filled with water. The counter-pressure of the steam must naturally decrease as it cools and condenses. As long as the lamp is under the flask, the pressure of the steam is stronger than that of the air, and the steam, being continually generated, forces the air previously contained in the flask into the water of the beaker-glass. This reflux of liquids is particularly to be feared, when such kinds of gases are conducted into water as are absorbed by it readily, and in large quantities. This is prevented by passing through the cork a second glass tube open at both ends, and letting it reach nearly to the bottom of the flask, by which tube air can penetrate into the flask as the pressure of steam diminishes. This contrivance is called a *safety-tube*.

Fig. 46.



93. *Barometer.*—It has been proved by exact calculation that the atmosphere presses upon the earth with a force equal to that of a layer of quicksilver 30 inches deep, or a layer of water 13½ times deeper (34 feet), water being 13½ times lighter than quicksilver. The instrument by which the amount of atmospheric pressure can be determined is called the *barometer*.

Fig. 47.



Fill a glass tube, 32 inches in length, one end of which is closed, with quicksilver; close it with the finger, and invert it into a vessel of quicksilver; on removing the finger, the mercury will not run out, but will fall some inches, perhaps to *s* (Fig. 48). The height of the quicksilver, from *a b* to *s*, amounts to about 30 inches. The quicksilver does not fall lower, on account of the external pressure of the atmosphere, which is exerted on the quicksilver at *a b*, and not at *s*, since this end is closed. The column of quicksilver in the tube may be regarded as the counterpoise to the atmospheric pressure, and it is hence concluded that the latter exerts just as much pressure upon the earth as a column of quicksilver 30 inches high. If the tube be opened at the top, the pressure of the air on both extremities being then made equal, the quicksilver will flow from the tube. The space above the quicksilver, at *s*, is a vacuum, and is called the Torricellian vacuum, from the name of the inventor. In common barometers the tube is curved at the bottom, and provided with a bulb. This bulb is open at the top, and supplies the place of the vessel filled with quicksilver in the preceding figure. Here also the pressure is only exerted at one extremity, for the atmosphere can only press on the mercury contained in the bulb. The height from *o* (Fig. 49) to the top of the quicksilver amounts to about 30 inches.

Fig. 48.

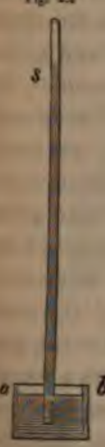
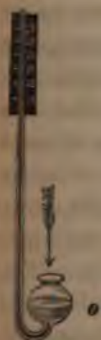


Fig. 49.



If weights be placed on one pan of a balance, the opposite one will rise, but on their removal it will sink. The same thing happens with the barometer. Any increase in the weight or density of the air presses the quicksilver up, and the barometer rises; but any diminution of weight will make it fall. The height of the quicksilver may be read off by affixing to the upper part of the tube a scale divided into inches and tenths of an inch. The mean state of the barometer is at 30 inches, and 31 is called a very high, and 29 a very low, state of the barometer. In this part of the country, as a general rule, the north and west winds cause the barometer to rise, and the south and east winds cause it to fall. The former winds, blowing chiefly from the land, are cooler, and at the same time drier, than the latter, which pass over the ocean, there becoming saturated with moisture; the former likewise come from colder into warmer, while the latter, on the contrary, proceed from warmer into colder regions; by which the capacity of saturation for vapor is increased in one case and diminished in the other. Hence it is very natural that, when north and west winds prevail, it should rain less frequently than during south and east winds; and that the former winds are dry, while the latter are damp. This is perhaps the principal reason why barometers are regarded as weather prophets.

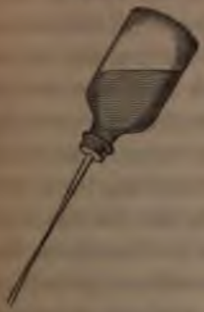
Why water does not flow from a jar inverted over the pneumatic trough, why it continues to flow through a syphon after the air has been exhausted, why liquids will not run into a vessel when the air is confined, or why water will only rise to the height of 34 feet in a suction pump, are questions that scarcely require further explanation.

94. If the pressure or tension of a confined quantity of air be increased, by compressing it either directly or

by the addition of more air, it can be forced to stream out from a small opening with great rapidity, as is shown on a small scale in the common bellows, and on a larger scale in the blacksmith's bellows. Should there be water before this opening, the air will press it out in a jet or stream.

Experiment. — Take a piece of a fine glass tube, drawn out to a point, and adapt it, by means of a perforated cork, to a bottle. Fill the bottle half full of water, and blow into it through the point of the tube; when the blowing ceases, the air will escape in a stream. But if the bottle be inverted as soon as the air is blown in, then the water will be spurted out by the compressed air above. Such an apparatus (the *Spritz* or washing-bottle) is frequently employed for washing residues or precipitates remaining on filters, in order to free them from soluble matter. There is a similar contrivance connected with the common fire-engine, called the wind-hose, and employed for throwing an uninterrupted stream of water.

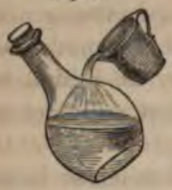
Fig. 50.



95. *The pressure of the atmosphere* exerts great influence *on the boiling* of water, and of other liquids. If water is brought to boiling when the quicksilver in the barometer is very low (in foul weather), brisk ebullition will take place at about 99° C.; when the quicksilver is is very high (in clear weather) boiling will not occur under 101° C.

Experiment. — Heat a flask half filled with water till the water *boils briskly; then* remove it from the

Fig. 51.



fire and quickly cork it; the b ing immediately ceases, but v commence again if cold water poured over the upper part of flask. In this manner it can be m to bubble or boil, even though it only lukewarm. There is no air in flask, it having been expelled by steam, and it could not reënter it, on the cooling condensation of the steam, on account of its hav been closed. Consequently there is no pressure of on the water, and it will boil even at a temperatur 20° C. The boiling ceased on account of the pres of the steam upon the water; but the steam being c densed by the cold water, the pressure was so m diminished, that a portion of water again became a form with a boiling motion. In many manufactor an appropriate apparatus has been contrived for boil and evaporating in a vacuum, as, for instance, in su houses.

The air is densest at the level of the sea, and thin in proportion to its distance from the earth, as ther less air above it. Hence the mercury will stand lo and water boil more easily, on the top of a mount than in the valley below. On the top of Mont Bl quicksilver rises only to the height of 16 inches in barometer, and water boils at 84° C. Hence the bar eter and the boiling point of water may be emplo for calculating the heights of mountains.

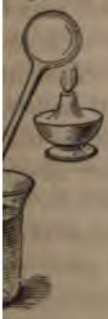
96. As water boils more easily under diminis pressure, so *it boils with more difficulty when the p sure is increased.* An increase of pressure can be duced, not only by the air, but by the steam of the ter itself, if new steam be constantly generated, w

ıpe of that already formed is prevented. This is ıe by heating water confined in a strong and losed vessel. For this purpose a Papin's Di-ıay be used, in which water may be heated to ıperature of 200° C., and indeed still higher, n open vessels it cannot be heated above 100° C. ımount of steam in it is twice as much as in an ɾed vessel, the pressure is said to amount to two heres; if there is 3, 4, 5, 10, 20 times the quan-ɜre is said to be a pressure of 3, 4, 5, 10, 20 at-ɾes. Vessels of this kind are often employed to complete penetration of the water into solid and bstances. Thus, for example, water at 100° C. ɜs the gelatinous matter only on the surface of ıes, whilst water at a temperature ranging from 120° entirely penetrates the bones, and extracts ıtine also from the interior of them.

ir and Heat. — *Heat expands the air* in quite the ɾay as it does solid and liquid bodies, but to a ɾreater extent.

riment. — Dip a glass tube, provided with a bulb, into water, and heat the bulb gently; a part of the air is expelled, and escapes in bubbles through the water; consequently, there is not room enough in the bulb for the heated air; but it requires a larger space than it did in its cold condition. It follows from this, also, that the warm air is lighter than cold. If the lamp be removed, the air remaining in the bulb will contract on cooling, and water will

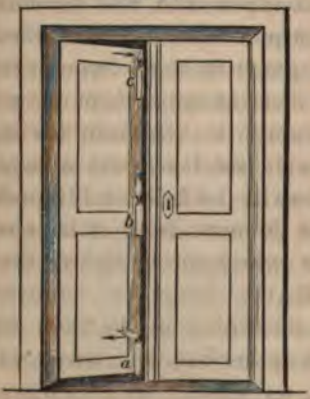
Fig. 52.



be pressed up into the bulb, replacing the air which has been expelled.

98. *Current of Air.* — A great many phenomena of daily occurrence may be explained by the difference in levity between warm and cold air. When a fire is kindled in a stove for the heating of an apartment, the air immediately in contact with the stove is first heated, becomes lighter, and ascends; colder air rushes in to supply its place, and this is likewise heated and ascends; consequently, a constant circulation of air is kept up. By a similar circulation, the whole atmosphere of the earth is kept in continual motion. At the equator the strongly heated air ascends and moves in the upper regions of the atmosphere towards the poles, while in the lower regions the current of cold air flows from the arctic zone towards the equator, in order here to restore again the equilibrium, disturbed every moment by the ascent of the warm air. These regular currents of air, the direction of which is somewhat diverted by the revolution of the earth on its axis, are called trade-winds.

Fig 53.



In every heated apartment, a difference between the heat of the air near the ceiling and that near the floor is very perceptible. If a door or window in such a room be opened, a current of air is produced, the direction of which may easily be perceived by holding a lighted candle in the opening; the flame, when held above, at *c* (Fig. 53), is blown *from* the room; when placed below, at *a*, it is blown *into* it; consequently, the light warm air above rushes out of the room, and is replaced by heavier and colder air from below. A draught of air is also noticed in passing from the sunshine into the shade; where the sun shines, the warmer air ascends, and the colder air from the shade supplies its place. For the same reason, a current of air is produced wherever a fire is burning, in every stove, and round every lamp.

The air-balloons, first constructed by Montgolfier, strikingly show how buoyant air may be rendered by heat; these are caused to ascend merely by filling them with air, kept continually hot by a fire beneath.

99. *Gases.* — Formerly, atmospheric air only was known, but chemistry has shown that there are various kinds of air, light and heavy, poisonous and innocent; some which are combustible, others not so, but which will support combustion, and others which extinguish it. It has also been shown that some sorts of air are concealed or chemically bound in many solid and liquid bodies, in which, from their external appearance, the presence of gases would never have been suspected; as, for instance, oxygen in oxide of mercury, and oxygen and hydrogen in water. These kinds of air are commonly called *gases.* The aeriform state is their natural condition, and they only assume the solid or liquid state on compulsion. Their densities, like solids and liquids (§ 23), are likewise expressed in numbers; but it must be remembered that in this case *atmospheric air*, and not water, is assumed as *unity.*

Vapor. — Many other bodies become aeriform on being heated, some quite easily, as alcohol and water; others with more difficulty, as sulphur and mercury;

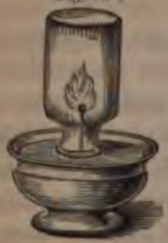
but on being cooled they lose their gaseous form, and assume again the liquid or solid state. Such species of air are called *vapor* or *steam;* they become gaseous only upon compulsion, their natural state is liquid or solid.

Composition of Air.

100. The last question concerning air is, What are its component parts? for that it is not a simple substance, not an element, has already been stated.

Experiment. — Fasten a piece of tinder to a wire, drop some alcohol upon it, and hold the wire in a vessel containing water, so that the tinder may be some inches above the water. Then kindle the spirit, and immediately place an empty flask over it, so that the mouth of it may dip into the water; the flame will soon cease burning, and some of the water will rise into the flask, in proportion to the amount of air disappearing during the combustion. The consumed air was oxygen, which united with the constituents of the alcohol. Close the flask tightly with the finger, shake it briskly, and again open it below the water, when a little more water will enter. The air which is in the flask is called *nitrogen;* it is sometimes called *azote* (α privative, and ζωή, *life*), from its inability to support respiration. It forms the chief element of atmospheric air; this consisting of four measures of nitrogen, and only one of *oxygen.*

Fig. 54.



NITROGEN OR AZOTE (N).

At. Wt. = 175. — Sp. Gr. = 0.97.

101. *Nitrogen gas*, the preparation of which has just been given, is erroneously called *azote*, as we are continually breathing it without perceiving any injurious effects from it; it stops respiration only when it contains no oxygen, and because it contains none. The human body is so constructed, that it will not thrive on substances intended as nourishment if they are presented to it in their purest form. Strong alcohol acts as a poison, but when diluted with four or five times its quantity of water, as in wine, it is invigorating. Even the respiration of oxygen would soon destroy life, were it not diluted with four times its measure of nitrogen, as in atmospheric air.

Nitrogen has neither color, smell, nor taste, and in a chemical point of view it must be regarded as a very inert or indifferent body, since it does not combine directly with any other substance. If we would combine it with another body, we must adopt a circuitous method. It is very widely diffused in nature, particularly in the organic kingdom, for we find it in all plants and animals. It is also contained in saltpetre or nitre, whence its name *nitrogen* (generator of nitre); its symbol is N.

102. Besides oxygen and nitrogen, air contains *vapor* and *carbonic acid*. The presence of the former is rendered obvious by the fall of rain, snow, dew, &c.; and that of carbonic acid can easily be determined by letting lime-water remain exposed to the air, as in § 46, or by shaking it in a flask containing air. Lime has an affinity for carbonic acid, and forms with it an insoluble salt (carbonate of lime, or chalk). This occasions a

cloudiness in the liquid; it is the affirmative answer to the question put by the lime-water to the air. If you ask, What is the source of this carbonic acid? the rely is, It is formed wherever substances are burning, wherever men and animals are breathing, and wherever decay and putrefaction are taking place.

In 100 measures of atmospheric air are contained, —

79 measures of nitrogen, or N.
21 " " oxygen, " O.
$\frac{1}{30}-\frac{1}{15}$ " " carbonic acid, " CO_2.
and variable quantities of water, " H O.

In crowded rooms, and other confined places, the air becomes deteriorated; that is, poorer in oxygen and richer in carbonic acid.

That the air also contains other foreign ingredients is not strange, since it is the constant receptacle of volatile substances and dust. The air coming from the Spice Islands, even at the distance of eight or ten miles, is impregnated with the odor of cinnamon and cloves. The dust contained in the air can be discerned in the sun-beam, &c. These ingredients are usually so small, that they can be determined neither by weight nor by measure.

COAL AND FIRE.

CARBON (C).

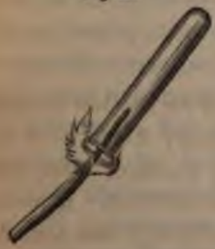
At. Wt. = 75.

103. If a piece of wood be placed on the hot hearth of a stove, it becomes brown, and finally black, — it is *charred*. If water be poured over a burning chip, the latter is extinguished, — it is likewise *charred*. A piece of linen, when inflamed and immediately smothered, becomes tinder. Tinder is *charred* linen. In the first

case, the heat was not sufficiently strong entirely to consume the wood; in the second, the complete burning was prevented by quenching, and in the third by the exclusion of air. *All animal and vegetable substances, if only partially burnt, are converted into coal.* As coal, on exclusion of the air, cannot be melted, even in the strongest heat, so the exterior of it is very different, according to the character and structure of the substance from which it was prepared; indeed, this difference often extends itself throughout the interior structure, as in charcoal, soot, coke, bone-black, &c. In the charring of organic bodies the coal is not generated, but it previously existed in them, though in chemical combination with other substances, which are principally driven off by heat, as is obviously the case from the fact that the charred body weighs much less than the original substance. All animals and plants consist, therefore, partly of coal; or, in chemical language, of Carbon = C.

Carbon also exists in the mineral kingdom. It forms the principal element of pit coal, brown coal, &c., which have all been formed from the vegetation of an earlier period. It is found almost pure in the diamond and in the graphite, and, combined with oxygen, is contained in limestone, marble, chalk, and various other minerals.

Fig. 55.



104. Charcoal (C containing a little ashes.)

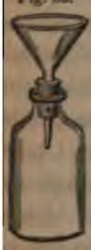
Experiment. — Gradually introduce a burning splinter of wood into a test-tube. The part outside of the tube only will burn with a flame, while that within merely chars, because the air is excluded. On the same principle, charcoal is prepared on a large scale. Piles of wood (charcoal kilns) are erected, which are covered with turf and moistened earth, and the wood is then kindled. This would be extinguished, however, for want of air, if holes were not made, by wooden pokers, at different parts of the kiln, through which fresh air may be admitted, and the burnt air may escape. Only so much air should be admitted as is necessary for carbonizing or half-burning the wood. When this has been accomplished in the neighbourhood of the holes, they must be closed, and new ones made at other points. At last all the openings are carefully stopped, that the fire may be suffocated. When cold, the wood will be found thoroughly burnt to blackness and charred, the shape of the knots and rings being still perceptible. One pound of wood yields about one quarter of a pound of charcoal.

105. *Experiments with Charcoal.*

Experiment a. — Weigh a piece of freshly-burnt charcoal, and let it remain for a day in a moist place; it will now weigh more than before, owing to its having *imbibed air and moisture.* If the coal be now put into hot water, the air will escape from the coal in numerous bubbles, being expelled by the heavier water, which replaces the air in the small interstices or pores of the coal. The snapping of such coals when placed upon the fire is hereby easily explained; the gases and vapors are expanded to such an extent by the sudden heat, that the coal is forced asunder, with a sort of explosion. Polished steel articles are often packed up in charcoal dust, that the air in the interior of the package may be kept dry, thus protecting the steel from rusting. *Pulverized charcoal,* on account of its absorbing power, may lso be used for purifying sick-rooms, and other apartments filled with deleterious vapors and gases.

Experiment b. — Grind freshly-burnt charcoal to a oarse powder, and place it on a filter. Then pour over t some red wine, or some water colored black by a few drops of ink; the liquid will pass through the filter nearly or quite colorless, the coal having *absorbed* or retained the *coloring matter*. Sugar-refiners take advantage of this property of charcoal in bleaching their brown syrups.

Fig. 56.



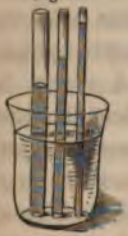
Experiment c. — Foul stagnant water *is deprived of its bad taste*, and is rendered clear and colorless, by being filtered through charcoal. In some large cities, where there is a carcity of potable water, it is not unusual to filter it through charcoal. Grain, likewise, which has become musty, may be rendered sweet by intimately mixing it with pulverized charcoal, and allowing them to remain some weeks in contact. Coal will also retard decay in vegetable and animal substances for a long period, and water remains pure for years in vessels which have been charred upon the inside; potatoes may be kept in cellars longer, without sprouting or rotting, when laid in with coal-dust; and meat, when packed in t, passes more slowly into a state of putrefaction.

Experiment d. — Charcoal renders ordinary brandy leasanter in taste and smell, by absorbing into its ores an acrid volatile oil, *fusel oil*, with which some rude brandy is contaminated. Coal deprives beer of ts bitterness, by absorbing certain *component parts of he hops.*

106. The cause of this remarkable power of coal to ttract and retain within itself such various substances, lepends on its spongy, porous character. If a plate of

water rises in it, and the rise in the tu

Fig. 57.



in proportion to the decr
ameter. Such tubes pres
face of glass to a sma
liquid, and the sides are
proximity, that they aid
drawing up the water i
This sort of adhesion is c
attraction. It is this whic
rise in the lamp-wick, th
water in blotting-paper, and the diffusio
through sugar and plastered walls. In
ner, *all solid bodies which have many po*
quently much surface, attract fluids and g
of charcoal, the size of a walnut, is
many hundreds of partitions, which, if
placed by the side of each other, would c
thousand times larger than the piece
covered. The force of attraction of thi
is so powerful, that the coal can absorb
times more than its own bulk of

less extent, is developed in charcoal when it absorbs gases; the charcoal may be heated even to redness, undergoing spontaneous combustion, by heaping together large masses of it in a pulverized state, and many an unfortunate accident has occurred from this cause, especially in factories for the manufacture of gunpowder.

Hydrogen and oxygen, however long they remain in contact, do not enter into chemical union, but when the mixture is brought into contact with spongy platinum they instantly unite, forming water. This will be easily understood, when it is remembered that chemical force acts only at insensible distances, and consequently only when substances are in the very closest contact. In spongy platinum, as in other porous bodies, gases can be condensed to the 80th, and indeed, in the former case, to the 800th part of their volume; they must therefore touch each other from 80 to 800 times more closely than in their natural condition.

107. Not only charcoal, but the following *varieties of coal*, have many different applications.

Soot, or *lamp-black*, (C containing empyreumatic matter,) is coal in a state of minute division, which is deposited from carbonaceous gases, commonly from illuminating gas; for instance, from the flame of pit-coal, wood, oil, rosin, &c., when during the combustion there is an insufficient supply of air. One variety of superior quality is called lamp-black. (§ 116.) The soot must be freed from the empyreumatic substances, either by igniting it thoroughly in a well-closed vessel, or by treating it with strong alcohol. Soot is well known as a most important black coloring substance (Indian ink, printing-ink).

Coke, or charred pit-coal, (C generally containing considerable quantities of ashes,) has a gray color, is more or less porous, is very hard, and has a metallic lustre; it burns without forming soot, and gives out an intense heat; hence it is an excellent fuel, and especially adapted for the smelting of iron, and for the heating of locomotive boilers. Coke is obtained as a secondary product in the preparation of illuminating gas from pit-coal. (§ 118.)

Bone-black (C intimately mixed with bone-ashes, and generally also with some azotized substances) is obtained by heating bones in close vessels. The coal contained in it amounts only to about one tenth part of the whole, the other nine tenths being bone-ashes; but notwithstanding this, its decolorizing power is so strong, that it is preferred to all other kinds of coal as a means of abstracting color from the syrup of brown sugar, or from other dark liquids.

Two sorts of carbon found in the mineral kingdom, viz. graphite and the diamond, possess very remarkable, yet different, properties.

Graphite, or plumbago, (crystallized *black* carbon,) a gray substance, having a metallic lustre, imparts its color so readily to other bodies, that it is used for making lead pencils, and for giving a black polish to iron articles, such as stoves, &c.; it is so soft and lubricating, that it is added to grease for the purpose of preventing friction in wheels and machinery; it is also so nearly incombustible, that crucibles are made of it, which endure the strongest fire without burning (blue-pots).

Diamond (crystallized *colorless* carbon) is the hardest of all bodies. In external appearance it has not, indeed, the slightest resemblance to coal, yet it can be entirely burnt up in oxygen, and carbonic acid is the only product obtained from it, and exactly so much is obtained as would have resulted from the combustion of an equally heavy piece of charcoal or coke. In order to crystallize a substance, it must first be rendered fluid, which is done either by melting or dissolving it. Coal can neither be melted by the strongest heat, nor dissolved in any known liquid. Should a method ever be discovered for rendering it liquid, then diamonds could certainly be artificially imitated.

108. Carbon shows very clearly how one and the same body can have quite different forms and different properties. In charcoal, soot, coke, and animal carbon, it is black without any determined shape (*amorphous*), and very combustible; in graphite it is black, with a crystallized foliated structure, and is nearly incombustible; in the diamond it is colorless, and is crystallized as a four-sided double pyramid (octahedron), and is likewise almost incombustible. Hence carbon is said to be *dimorphous*, having two different crystalline forms. If a body can assume more than two crystalline forms it is said to be *polymorphous*, having many forms.

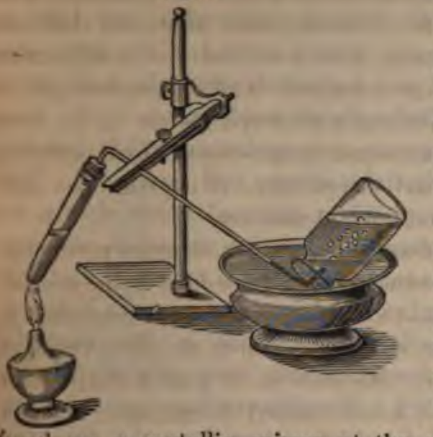
This property, which many elements have, of assuming different forms, is also called *allotropic* (from ἀλλοτρόπος, *different nature*), and it is designated by annexing Greek letters to the chemical symbols. Accordingly carbon occurs in the three following allotropic states or modifications; as $C\alpha$ in diamond, $C\beta$ in graphite, and $C\gamma$ in charcoal.

The cause of this difference depends upon the relative position of the particles or atoms constituting the body towards each other. The same fibres of cotton, which, after carding, are parallel to each other, when matted together without order, constitute paper or paste-board; when loosely woven together, wadding; when twisted, yarn or thread, and when they are made to intersect each other regularly, or in some intricate manner, cloth, stockings, velvet, &c. Nature also impresses different forms upon the same substance, but in a still more varied and artistical manner. The adaptation of the atoms to each other is not rendered visible to us, even by the aid of the strongest microscope; but this theory may be regarded as correct, since it explains the subject in a simple and natural manner.

109. *Coal and Oxygen.* — Coal undergoes no change on exposure to the air, or when imbedded in the ground. It is not decomposed at common temperatures, that is, it does not enter into combination with the oxygen of the air or of water. But this, as is well known, takes place very readily, when heated to redness. It then burns and disappears, with the exception of a small quantity of ashes. The heat thus developed is the result of the chemical union of the carbon with the oxygen of the air. The gas generated is called *carbonic acid*, which forms, with lime-water, a white precipitate (carbonate of lime), as has been stated previously. Carbonic acid consists of one atom of carbon and two atoms of oxygen, consequently its formula is $= C\,O_2$. It may also be obtained as follows.

Carbonic Acid. — *Experiment.* — Mix 109 grains of oxide of mercury with four grains of charcoal, and heat them in a test-tube (§ 56). A lighted taper introduced into the gas is extinguished, a sign that it contains no free oxygen. If you shake it with lime-water, the liquid becomes turbid, and on shaking the flask the finger is sucked in, or rather it is pressed into the neck of the flask by the atmospheric air, a proof that the gas was absorbed by the lime-water, and that a vacuum was produced within the vessel. If the oxide of mercury had been heated by itself (§ 56), it would have

Fig. 58.



separated into mercury and oxygen; and this also happens in the present experiment, but the oxygen does not escape as such, it having previously united with part of the coal; the gas evolved is *carbonic acid.* The mercury is found, as a metallic mirror, at the upper part of the test-tube. After the experiment is finished, some coal still remains in the test-tube, for only 3 grains of it have united with the 8 grains of oxygen contained in the oxide of mercury; consequently, in the same proportions as in the burning of charcoal in pure oxygen. (§§ 63, 70.) We see that 3 grains of carbon combine with as much oxygen as 101 grains of mercury, or (§ 70) with as much oxygen as 8 grains of sulphur, 6 grains of phosphorus, 23 grains of sodium, or 20 grains of iron. These numbers are called *equivalents;* they indicate that 3 grains of carbon have the same chemical value as 101 grains of mercury, or as 8 grains of sulphur, &c. In the same sense, when we see a steam-engine perform, in one day, the work for which four horses or twenty-four men were required, we say that the power of the steam-engine is equivalent to the power of four horses or twenty-four men. (§ 164).

110. *Carbonic Oxide Gas.* — When charcoal, during combustion, has a sufficient supply of air, then carbonic

acid, or $C\ O_2$, is formed; but if there is a deficiency of air, then 3 grains of charcoal unite with only half as much oxygen, namely, with 4 instead of 8 grains, and there is produced but half-made carbonic acid, as it were, which is called carbonic oxide gas $= C\ O$. Carbonic oxide gas is extremely poisonous when inhaled, and constitutes what the miners call coal-gas. This gas is always formed when charcoal burns slowly, for example, in a chafing-dish, because the ashes, accumulating round the coals, obstruct the access of air; and it is also formed when the damper of a stove is closed, before the coal is burnt out, since in this case the draught of air, and consequently the supply of sufficient oxygen, is prevented. Notwithstanding repeated warnings, accidents not seldom occur from the fumes of burning charcoal. Carbonic oxide burns, when kindled, with a blue flame; it takes up the deficiency of oxygen not supplied to it by the air while forming, and is converted into carbonic acid; that is, it takes up as much again oxygen, and $C\ O$ becomes $C\ O_2$. The blue flame which is always perceived on feeding the fire with fresh coals, or in large masses of glowing coals, is burning carbonic oxide gas.

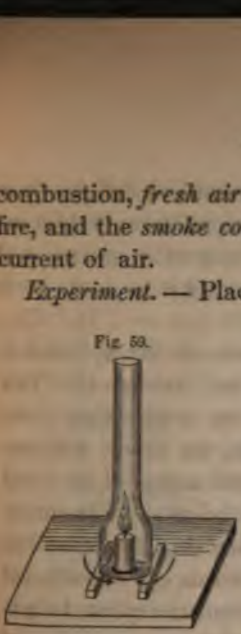
COMBUSTION.

111. Every combustion with which we are familiarly acquainted is caused by a rapid chemical union of combustible bodies with the oxygen of the air, and the process may be regarded as one of oxidation. The consumed or oxidized combustible substances, that is, the compound of the fuel with oxygen, are mostly aeriform. We call them smoke, which will not support combustion. It follows from this, that, in order to maintain

combustion, *fresh air must be continually supplied* to the fire, and the *smoke conducted off.* This is effected by a current of air.

Experiment. — Place the glass cylinder of a lamp over a lighted candle, which will soon be extinguished, because no fresh air can enter from below. The candle is also extinguished when the cylinder is covered at the top, although the cylinder is so held that the air can gain admittance from below; it is extinguished in this case, because the escape of the burnt gases is prevented. If the cylinder is placed uncovered on two pieces of wood, the candle continues to burn quietly, and by holding a taper recently extinguished near the lower opening, it will be obvious, from the direction of the smoke, that air rushes in at the bottom, but escapes at the top, having become hot and lighter during the process of combustion.

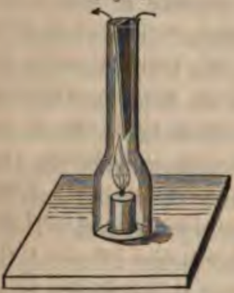
Fig. 59.



The hand can be held quite close over the flame of a lamp without being burnt, but if the flame be surrounded by the glass cylinder, the heat cannot be borne, unless the hand be much farther removed from the flame. In the former case the hot air radiates in all directions, while in the latter it is confined within the walls of the cylinder; consequently the hot air must issue from the top *more rapidly,* and the cold air enter *more rapidly* from below to replace it. Owing to this increased current of air, cylinders effect a brisker and more perfect combustion, and cause a brighter and stronger illuminating flame.

Chimneys are to fire-places what cylinders are to

Fig. 60.



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112. In common lamps air l
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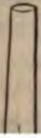
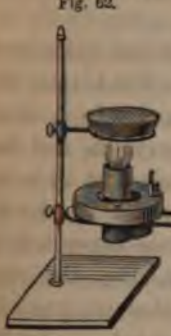
Fig. 61.



tre of the flame, causing it to burn in the form of a hollow ring. They are also called lamps with a double draught. The so-called *Berzelius Spirit-Lamp*, universally employed in chemical laboratories, when a higher heat is required than a common spirit-lamp can yield, is constructed on this principle. It is made of brass plate, is attached to a brass stand, and is provided with several rings of various sizes for holding porcelain dishes, crucibles, and other vessels, that are to be heated. In using this lamp, care must be taken that sufficient space be left between the vessels and the chimney for the escape of the hot air, and for the diffusion of the upper part of the flame. If this be not done, the combustion will be imperfect, and consequently less heat be given out. When it is desired to feed the lamp with more alcohol, the flame must first be extinguished, as otherwise the alcohol might take fire and cause serious inconvenience.

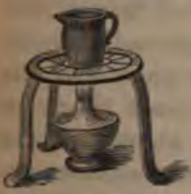
Fig. 62.



113. In order to kindle a substance, and to keep it continually burning, it must first be *heated to a certain point, and then maintained at this temperature.*

Experiment. — Heat in a small vessel some ashes or sand, on which a few friction-matches have been placed; the latter, or more correctly the phosphorus on them, will not inflame until the ashes are heated to about 65–70° C., which can be readily ascertained by the thermometer.

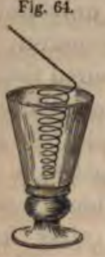
Fig. 63.



114. *Slow and rapid Combustion.* — *Experiment.* — If

a coil of fine platinum wire, being raised to a white heat in the flame of a spirit-lamp, be plunged quickly into a heated goblet into which a teaspoonful of strong alcohol has been poured, it will continue to glow in the vapor of the alcohol, whilst it would soon have ceased glowing in the air. The alcohol undergoes a *slow* combustion, that is, it unites with a small quantity of oxygen, and the heat thus liberated is sufficient to keep the wire *red-hot.* A disagreeable sour smell will also be perceived, proceeding from the new combination formed between the alcohol and oxygen during the slow combustion, and which may be regarded as partially burnt alcohol. When alcohol is kindled, it burns briskly and completely, and the products emit no smell; therefore the combinations formed during the rapid or complete combustion must be different from those formed during the slow or incomplete combustion. Something similar to this is perceived with all other combustible bodies. The unpleasant odor caused by the singeing of the hair, the scorching of wool, the boiling over of milk, and the dull burning of blotting-paper, is the consequence of incomplete combustion; if they had been completely burnt, no bad smell would have been observed.

Fig. 64.

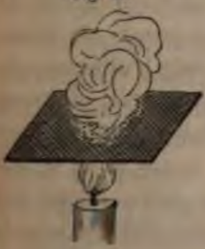


If in the last experiment ether be substituted for alcohol, and the wire be brought to a white heat, it will cause it to burst into flame; but the red-hot wire will not kindle it. The temperature of the red-hot wire is not sufficient to produce rapid combustion of the ether, but a stronger heat is required. As phosphorus did not inflame until it was heated to 70° C., nor ether until a higher temperature was attained, so all combustible substances require a certain degree of heat at which to enter into rapid combustion, some a higher and some a lower degree. When burning bodies are cooled below this temperature, they are extinguished. Red-hot iron will continue to burn in oxygen, but not in common air; heat enough is evolved during the combustion in oxygen to keep it burning, while, in the five times slower combustion in the air, sufficient heat is not evolved for the continuance of this process. Pit-coal requires for sustained combustion a stronger heat than wood; therefore the pieces must lay close upon each other in the grate or stove, or they will cool off too much and cease burning; wood continues to burn, even when spread loosely about on the hearth of the stove. A glowing coal is extinguished much sooner when placed on iron than on wood, for the iron, a good conductor of heat, withdraws the warmth more rapidly than wood, a bad conductor.

Even the flame of a candle, or of a spirit-lamp, can be cooled to such a degree by iron as to be extinguished.

Experiment. — If you introduce a piece of wire gauze, such as is used for sieves, into the flame of a lamp, this will be suppressed as though a piece of tin-plate were held over it, and smoke, but no flame, passes through the net-work. This smoke, if kindled by a match, will again burn. The smoke in passing through the iron gauze has become cooled down below the temperature necessary for burning; if this temperature be restored by the application of a taper, or by the gauze having reached a white heat, the smoke is again kindled.

Fig. 65.

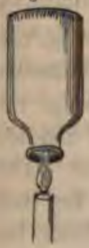


An illustrious English chemist has made a successful application of this principle for the prevention of the explosions so often occurring in coal mines. In many mines a combustible gas (fire-damp, or light carburetted hydrogen) issues from the fissures of the coal, which, mixing with the atmospheric air, forms an explosive gas, which might be fatal to the miner who should carry a burning lamp into a vein filled with such a gas. But if the flame be inclosed within an iron net-work, the explosive gas would only burn within the cage; the miner thus warned has time to withdraw, and this dangerous gas is afterwards expelled by appropriate means. (*Davy's Safety-lamp.*)

115. *Complete Combustion.* — In the combustion of hydrogen, water is formed (§ 87), and in the combustion of carbon, carbonic acid (§§ 63, 109). Both of these products are also formed in the combustion of most other substances familiar to us, as these generally contain hydrogen and carbon, on which depends their capacity for burning.

Experiment. — Invert an empty flask over a burning candle, so that it may receive the hot gases as they form; it becomes clouded on the inside, from the deposition of moisture which is condensed from the smoke upon the cold surface of the glass. This smoke consequently contains *vapor*. This explains why, on heating a vessel over a lamp, moisture is deposited on the outside as long as it remains cold. Pour lime-water into the flask, and agitate it. The liquid will become turbid, and deposit, on standing, a white powder (carbonate of lime); thus the smoke contains also *carbonic acid;* some *nitrogen* also must of course be present, as it existed in the atmospheric air which was used in maintaining the fire.

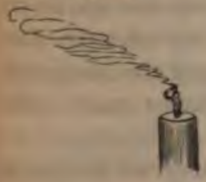
Fig. 66.



These component parts exist likewise in the smoke which issues from the chimneys of houses, whether formed from the combustion of wood, pit-coal, or brown coal; and are contained in the invisible current which ascends from an alcohol or oil flame.

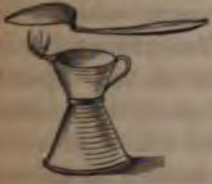
116. *Incomplete Combustion.* — *Experiment.* — If you extinguish a lighted candle having a long snuff, you can rekindle the smoke ascending from the wick, even at some distance; this smoke consists of the combustible gases into which the tallow has been converted by heating. It is partially consumed tallow, and has an unpleasant smell. On being extinguished, sufficient heat is not retained for its complete combustion, but this commences again when the smoke is heated and kindled by a match. Completely burnt tallow, that is, tallow converted into carbonic acid and water, has no smell.

Fig. 67.



Experiment. — If you stop up the draught of a burning astral or Argand lamp (§ 112) with a piece of paper, the flame will immediately become dark and red, emitting a thick black smoke, which has a very disagreeable odor, and which covers a piece of paper held over it with soot. There is an *incomplete combustion of the oil, owing to the exclusion of the air;* a part of the carbon contained in the oil remains unconsumed, and escapes as *soot.*

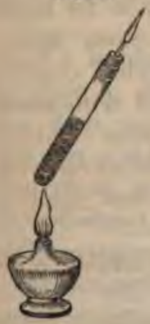
Fig. 68.



Experiment.—Refrigeration gives rise to the same phenomenon, as, for example, when an iron spoon is held over the flame of a common oil-lamp, so as partly to suppress it. The iron, being a good conductor, not only cools the flame, but it also obstructs the draught of air; a part of the carbon, therefore, remains unconsumed, and is deposited as soot upon the spoon. In this way watchmakers prepare *lamp-black* for marking their dial-plates. A tallow candle yields an invisible and scentless smoke when allowed to burn quietly, but, on the contrary, a sooty and disagreeably smelling smoke when the flame is cooled by blowing upon it, or moving the lamp about. In order to smoke meat rapidly, green or wet wood is burnt; this yields a thick, black smoke, because it cannot be heated above 100° C. as long as it contains water, and at this low temperature it is only incompletely consumed.

117. *Illuminating Gas and Flame.* — *Experiment.* — To acquire a clearer understanding of the products of *incomplete* combustion, put into a large test-tube some wood-shavings, and heat it, having previously adapted to the opening a cork, provided with a glass tube or a piece of pipe-stem (Fig. 69). The gaseous matter which is formed will pass through the tube, and, on being kindled, will burn with a luminous flame. Previously to being kindled, the shavings emit a sour and empyreumatic odor; this smell, however, vanishes entirely on burning. *Flame, then, is caused by burning gas.* Substances which do not become gaseous on combustion can only glow, but cannot burn with a flame. Some charcoal will remain unburnt in the test-tube, owing to a deficiency in the supply of air. An application of this principle is made

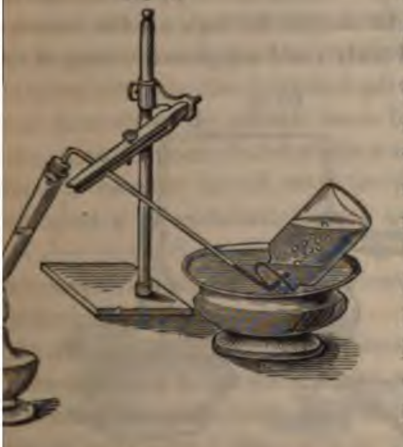
Fig. 69.



large scale in the preparation of *illuminating gas* ie heating of pit-coal, rosin, &c., in closed iron ves- Every candle and every oil-lamp, when burning, enerators of gas on a small scale.

8. *Experiment.* — Repeat the experiment with pulverized pit-coal, but conduct the gas, through a bent glass tube, into a jar placed over the pneumatic trough, and collect it as already described. The gas is colorless, and on being ignited burns like hydrogen, but with a far more luminous flame. Its chief constit- is indeed hydrogen, chemically united with some on (*carburetted hydrogen gas*). During combus- , both constituents of illuminating gas unite with oxygen of the air, and are converted into carbonic and water.

Fig. 70.

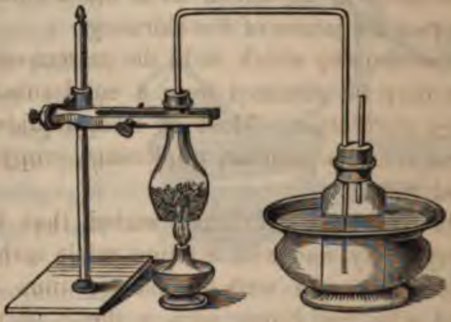


oke, already alluded to, which is a tolerably pure on, remains behind in the tube.

arbon forms with *hydrogen* a very numerous class hemical compounds; those with which we are best iainted are, — *a*) *light carburetted hydrogen* ($H_2 C$), h issues from the fissures of many coal-beds (firep, § 114), and is likewise always generated wher- vegetable matter is putrefying under water (marsh gas, § 446); owing to its larger proportion of hydrogen, it is lighter, and, on account of its smaller proportion of carbon, it burns with a paler flame, than *b*) *heavy carburetted hydrogen* ($H_4\ C_4$), commonly called olefiant gas (§ 503). These two gases ($H_2\ C$ and $H_4\ C_4$) form the principal constituents of the common illuminating gas.

119. *Experiment.* — Heat some pieces of wood, and conduct the volatile matter through a tube into a flask immersed in cold water, and adapt to the cork of the latter another open tube, for the escape of the *illuminating gas*. Two fluids will be condensed at the bottom of the flask; one a very thick viscid fluid, and the other a thinner watery substance. The first is called *wood-tar;* it is resinous, and is therefore insoluble in water. The other is called *wood-vinegar*, or pyroligneous acid; both its taste and action upon blue test-paper indicate that it is an acid. *Illuminating gas, wood-tar, and wood-vinegar did not previously exist in the wood*, but were formed during the incomplete combustion from its constituent parts, carbon, hydrogen, and oxygen. Such new-formed substances are called *products;* and in the present case, moreover, products of the in-

Fig. 71.

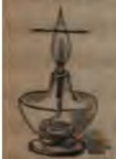


complete combustion (dry distillation) of wood. Hydrogen predominates in illuminating gas; oxygen in pyroligneous acid; and carbon in wood-tar; all of them, owing to the deficient supply of air, were but partially burnt, and they are hence capable of undergoing further combustion in the air, and, like the wood from which they originated, of being fully converted into carbonic acid and water. A portion of wood always remains incompletely consumed in our fire-places, and therefore soot is deposited in the funnels and chimneys; the tar and acid are also deposited, as a black shining substance, upon the jambs of the chimney.

The operation by which, as in the present case, liquid products may be obtained from a solid substance, is called *dry distillation*. Most of these liquids have a brown color, and a peculiar, unpleasant, empyreumatic smell and taste.

120. It has been previously stated that hydrogen burns very easily, and with a flame, while carbon burns more difficultly, and without flame; thus is easily explained why fuel burns with a flame at the commencement of the combustion, but finally only glows; it is the hydrogen which *first* burns with a *flame*, and afterwards the carbon, with a mere glow, without flame. All combustible substances that contain hydrogen and carbon burn in a similar manner. Burning wood presents the most convincing illustration of this fact.

Fig. 72.



121. The alcohol flame consists of two parts; the dark central part is alcohol vapor, and the bright envelope is alcohol vapor uniting chemically with the oxygen of the air. The tapering form of the flame is owing to the ascending of the hot gases, and

the rushing in of cold air from below. The alcohol is drawn up from the lamp by the capillarity of the wick (§ 106); it burns with a feeble lustre, but if a twisted wire or some other solid body be introduced into it, it will then burn vividly. If a thin wire is placed across the flame, it will be heated to redness near the margins of the flame, while in the interior it will remain dark; consequently, the external part is much hotter than the central part of the flame. The point of greatest heat is indicated by the mark in the figure, and vessels to be heated over the spirit-lamp should never be placed below this point. This may be rendered very evident by applying a friction-match to this part of the flame, when it will take fire at once; but not so quickly if thrust into the centre of the flame.

Fig. 73.

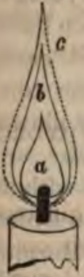
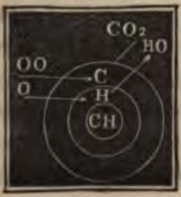


Fig. 74.



122. In the *flame of a lamp or candle*, three portions can be distinguished; in the *middle* (*a*, Fig. 73), the dark centre, consisting of illuminating gas (decomposed tallow); *around this* (*b*), the luminous cone, consisting of burning hydrogen, intimately mixed with carbon at a white heat; and *on the very outside* (*c*), a thin, scarcely perceptible veil, in which carbon is burning. If a horizontal section, through the centre of the flame, be supposed, it would present nearly the same appearance as in Fig. 74. The middle circle is carburetted hydrogen, or illuminating gas; the hydrogen of which burns *first*, and the great warmth thus evolved brings the carbon to a white heat (this is indicated by the second circle); and finally, in the exterior circle, the carbon is consumed. The heated

carbon in the second ring imparts to the flame its illuminating power, just as the glowing wire rendered the alcohol flame luminous. If a cold knife be introduced into the flame, a portion of the carbon will be so much cooled that it cannot burn, and will be deposited upon the knife in the form of soot. If a wire be held through the flame, the glowing part at the hot margins will remain clear, while soot will be deposited upon that part of it which is in the interior of the flame.

The *brightness* of a flame always depends, as the foregoing experiments show, upon the presence of a solid body, usually soot, which glows in the flame; if it be only heated to redness, the flame will give out a smoky red light, but, on the contrary, a brilliant light when heated to a white glow.

The four simple substances now treated of form the chief elements of plants and animals, and are hence called *Organogens* (generators of organic bodies).

RETROSPECT OF THE ORGANOGENS (OXYGEN, HYDROGEN, NITROGEN, AND CARBON).

1. As we distinguish on a small scale, within ourselves, body and spirit, so we distinguish also on a great scale, in nature, matter (body) and forces (spirit).

2. All matter is ponderable. Absolute weight determines the actual weight of a body in the air; specific weight the relative weights of substances of equal bulks.

3. Bodies occur in three aggregate states; they are either solid, liquid, or aeriform.

4. The earth may be regarded as the representative

of solid bodies; water, of liquid; air, of aeriform bodies; and fire, as the type of the natural forces.

5. The single particles of bodies are held together by a power called *cohesion*. It is strongest in solid, and weakest in aeriform substances.

6. This force is weakened by heat, strengthened by cooling; bodies are expanded by heat, and the single particles are removed from each other; by cooling, on the contrary, they are again contracted into a smaller space.

7. Heat also changes the aggregate state of bodies; it renders solid bodies liquid (melting), and liquid bodies aeriform (evaporation, boiling).

8. On cooling, gaseous bodies become fluid (distillation, rain), fluids become solid (hardening, freezing).

9. On the melting and evaporation of solid and fluid bodies, heat becomes *combined* or latent (production of cold); on the freezing of fluid and the condensation of gaseous substances, heat becomes *free* (production of heat).

10. All bodies contain, accordingly, latent heat, and the fluids always less than the gaseous.

11. Solid bodies also become fluid by *solution* in a liquid. If they separate again from such solutions in a regular form, they are said to be *crystallized.* Movableness and time are necessary for crystallization.

12. Gaseous bodies which on cooling easily become liquid, are called *vapors;* those which are converted into liquids with difficulty, or not at all, are called *gases.*

13. Cohesion of bodies can also be destroyed by cutting, breaking, &c.; hereby their form only is changed, their original constitution remaining the same. These are exterior or *mechanical changes.*

14. But changes also occur by which bodies are so entirely altered in their constitution and properties, that they can no longer be recognized as the original bodies, but must be regarded as new bodies. These are interior or *chemical changes.*

15. A power, more or less inherent in all bodies, is regarded as the cause of the chemical changes; it is called *affinity*, or *elective affinity.* In inanimate or inorganic bodies this power rules unrestrained, but in living or organic bodies it is regulated by the *vital power* of vegetables and animals.

16. Affinity acts only at insensible distances; when matter is in the closest contact.

17. Affinity is stronger between bodies in proportion to their greater dissimilarity, and so much the weaker the more they are alike.

18. Chemical changes may be produced in two ways; either by the combination of simple bodies into compound ones (synthesis), or by the separation of the compound bodies into their constituent parts (analysis).

19. By analysis bodies are finally obtained which can be no further decomposed; these are called simple bodies or *chemical elements.* About sixty of them only are as yet known. One element cannot be converted into another.

20. Almost every chemical compound may be decomposed by electricity or galvanism.

21. By heat, the affinity of bodies for each other is sometimes strengthened, sometimes weakened; heat assists both in combining and in decomposing bodies.

22. All chemical combinations take place according to fixed *measure* and *weight.* This conformity to law also prevails where substances combine together in several proportions (degrees of oxidation, &c.).

23. *Heat* is evolved during almost all chemical changes, and not unfrequently gives rise to the phenomenon of fire (combustion).

24. What is ordinarily called *combustion* is a combination of carbon or hydrogen with the oxygen of the air, — an *oxidation.*

25. *To oxidize* signifies to combine a body with oxygen. The body combined with oxygen is generally called an oxide.

26. There are two different sorts of oxidation, *acid* and *basic;* the metalloids form with oxygen, by preference, *acids;* the metals, by preference, *bases.*

27. Acids and bases have a very great affinity for each other; when they combine together, the acid properties of the former and the basic properties of the latter disappear (neutralization). The newly formed body is called a *salt.*

28. The chemical elements are designated by the initial letters of their Latin names (chemical symbols); from the latter chemical *formulas* are constructed, which represent the constitution of the compound bodies.

SECOND GROUP OF METALLOIDS: PYROGENS.

BRIMSTONE, SULPHUR (S).

At. Wt. = 200. — Sp. Gr. = 2.0.

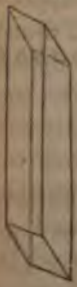
123. SULPHUR, an article very familiarly known, which, on account of its easy combustibility, is employed in the manufacture of matches, &c., has neither taste nor smell. It has no *taste,* since it is not soluble in water. When we throw some flowers of *sulphur* into cold or hot water, it is not dissolved. We

perceive taste only in such bodies as can be dissolved in water, since they alone will dissolve in the saliva; for example, there is taste in salt and sugar, but none in insoluble substances, as stones, charcoal, starch, &c. Sulphur has no *smell*, as it does not volatilize at the ordinary temperature. We can only perceive smell in a body when volatile, consequently gaseous or vaporous particles, are given off from it, and come in contact with the lining membrane of the nose.

124. *Experiment.* — Sulphur is *fusible*. Heat two ounces of flowers of sulphur in a small stone-ware crucible, over a spirit-lamp; it is converted, at a temperature a little above that of boiling water, into a thin, brownish fluid. If you pour some of it into cold water, you obtain again solid sulphur. If this, after being previously dried, is returned to the crucible, it will sink in the fluid mass, showing that solid is heavier than melted sulphur. Almost all other bodies behave in the same manner; ice, which floats on water, being an exception.

125. *Experiment.* — Sulphur may be crystallized. Let the crucible containing the melted sulphur stand till a crust has formed over the surface; break this quickly, and pour out the portion remaining fluid. Upon afterwards breaking the crucible, the cavity of the sulphur will be found lined with fine crystals, in the form of lengthened pillars (Fig. 75), which are called oblique rhombic prisms. This is the second method of forming crystals, and differs from the mode of obtaining those of saltpetre and salt (§§ 50, 52), inasmuch as in the one case the body was rendered liquid by solution, in the other by heat.

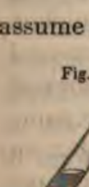
Fig. 75.



If the sulphur is allowed to cool quietly, without decanting the liquid portion, this also will become solid, and such a dense mass of crystals will be formed, that there will be no vacant space between them. This mass, on being fractured, presents a glistening appearance, owing to the reflection of light from the surfaces of the minute crystals. Such a body is said to be *crystalline*, or to have a *crystalline structure*.

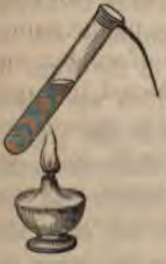
126. In different parts of the world, particularly in volcanic countries, large beds of sulphur (native sulphur) are not unfrequently found, and, in these beds, fissures and cavities studded with the most beautiful crystals, which required, perhaps, centuries for their formation. These native crystals have a very different form from those artificially prepared. They occur in pointed four-sided pyramids, applied base to base (Fig. 76); such a form is called an acute octahedron, because contained under eight acute triangles. Thus sulphur, like carbon in diamond and graphite, assumes two different forms; it is *dimorphous*.

Fig. 76.



127. *Experiment.*— Sulphur may be made to assume a still different state. Heat a test-tube, supported by means of a wire twisted round it, and filled with powdered sulphur, over a spirit-lamp; on fusing, the sulphur runs together, so that it only half fills the tube. The sulphur first becomes thin, like water, but on further heating it becomes brown, and so thick and viscid that the tube may be inverted without the sulphur flowing out. Thrown into water while in this condition, it forms a transparent, soft, elastic mass,

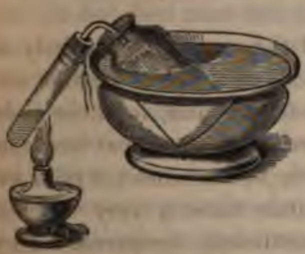
Fig. 77.



which, after a few days, is reconverted into solid sulphur. This sulphur, resembling melted glass, is said to be *amorphous*, a term applied to all other bodies, having no regular form; such as gum, pitch, glue, &c.

128. *Experiment.*—If the sulphur in the test-tube be heated still more strongly, at a temperature, perhaps, four times above that of boiling-water, it begins to boil, and is thereby converted into a reddish-brown vapor, *sulphur fumes;* thus sulphur is *volatile*, and may, like water, assume all the three states of aggregation (solid, fluid, and aeriform). Sulphur is twice as heavy as water, and the fumes six and a half times heavier than common air. Within the tube, the fumes of sulphur are transparent, and have a reddish-brown color; but after escaping, on the contrary, they appear as a yellowish smoke, being condensed by the cold air into a dust of solid sulphur. If these fumes be conducted into a glass jar, immersed in cold water, the sulphur condenses in it in the form of a soft yellow powder, known in commerce by the name of *flowers of sulphur*. In the preparation of sulphur on an extensive scale, the operation is conducted in large chambers. The process by which a volatile substance is evaporated and condensed again into a solid is called *sublimation*. In distillation, the vapor is condensed into liquid (the distillate), in sublimation, into a solid (the sublimate).

Fig. 78.



If, in this experiment, the receiver were not kept cool, it would gradually become so hot that the sulphur would pass over as a fluid, and on this principle native sulphur is purified on a large scale. The earthy impurities, not being volatile, remain behind while the sulphur is distilled over, and again condensed. The melted sulphur is commonly poured into moistened wooden moulds, and is then called *roll-sulphur.*

129. *Experiment.* — Fill a test-tube half full of soap-boiler's lye; add to it as much flowers of sulphur as can be taken up on the point of a knife, and boil the mixture for some time; a part of the sulphur will be dissolved, imparting to the liquid a yellowish-brown color. The clear liquid is now decanted, diluted with water, and vinegar added to it; it will immediately assume a milky appearance, owing to the separation of the sulphur in the form of an exceedingly fine powder, which is so light that a considerable time must elapse before it will subside. Collect the powder on a filter, wash it with water, and dry it at a gentle heat. It is called *milk of sulphur*, or *precipitated sulphur*, and is sulphur in its finest state of subdivision, caused by the separation of each of its particles by the water. Precipitated sulphur has a pale yellowish tint, but on being melted it becomes distinctly yellow, owing to the union of the single particles into a larger mass. This method is frequently employed in chemistry to convert solid substances into the finest powder. Such substances thus reduced to a fine powder are not unfrequently amorphous.

The solution of sulphur in lye is more complex than that of sugar or of salt in water; as several other peculiar combinations of sulphur with the component parts of water are formed at the same time. One of them, sulphuretted hydrogen ($H\,S$), is gaseous, and occasions the offensive smell which is emitted on the addition of vinegar to the solution of sulphur. The vinegar unites with the constituent of the lye, which then loses its power of holding the sulphur in solution.

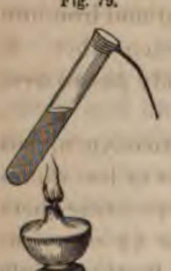
130. *Experiment.* — If sulphur be heated in a vessel with free access of air, for example, in an iron spoon, or be touched by some red-hot body, it *burns* with a blue flame; that is, it unites with the oxygen of the air, under the phenomenon of fire, and forms with the oxygen, as has been previously shown (§ 64), an irritating gas, sulphurous acid ($S\,O_2$). If another atom of oxygen be added to this, there is then formed the common and very important acid, called sulphuric acid ($S\,O_3$).

This property which belongs to sulphur, of igniting and continuing to burn at a very moderate heat, is the reason of its being so commonly used for all *kindling purposes.* By means of it, other bodies of more difficult combustion may be heated to the temperature at which they can continue to burn (matches, gunpowder, fireworks, &c.). The kindling of a simple coal-fire well illustrates how, by gradual transition from easily inflammable materials to those of more difficult ignition, the latter are finally brought to that degree of heat at which they will ignite and continue to burn. Thus, sparks of iron, thrown out by the striking of the steel, ignite the fine coal of the tinder; this kindles the matches, by means of which, first straw, then wood, and finally coal itself, are brought to the temperature requisite for burning. The following is the scale in the order of combustion: — tinder, sulphur, straw, wood, pit-coal.

131. Sulphur is the *strongest chemical body*, next to oxygen, and has, like it, a powerful affinity for all other elements.

Experiment. — Boil some sulphur in a test-tube, and

Fig. 79.



expose a very thin copper plate to the brownish vapor; the copper will glow vividly for some moments, lose its red color and flexibility, become gray and brittle, and weigh one quarter more than before. The newly-formed gray crystalline body is called *sulphuret of copper*. Both elements have intimately combined, and in fixed proportions. The properties of the sulphur, as well as of the copper, have entirely disappeared. The great heat produced is a consequence of the chemical combination, since, in accordance with a law of nature, heat is evolved wherever bodies chemically combine with one another, but in most cases the heat does not amount to actual glowing or combustion.

In a similar manner almost all other metals may be converted into sulphur metals. We find many of these, however, already formed in the earth, and miners call them glance, blende, or pyrites. The pyrites having the lustre of brass, and found in almost all pit-coal, is sulphuret of iron; red cinnabar is sulphuret of mercury, &c. The sulphuret of copper, artificially prepared as above, occurs also as an ore, and is then called *copper pyrites*.

Experiment. — Mix three fourths of an ounce of iron-filings, half an ounce of flowers of sulphur, and one fourth of an ounce of water, in a small vessel, and put it in a warm place; the mass becomes heated, the water evaporates, and in half an hour a black powder will be obtained, in which no particles of iron or of sulphur will be perceived; a chemical compound, *sulphuret of iron*, is formed. If the two substances be mixed together without water, no combination will take place, unless they be heated to redness; the water effects the combination, by bringing the particles of sulphur and iron into such close contact that they can attract each other. It is, as it were, the bridge by which one body passes over to the other.

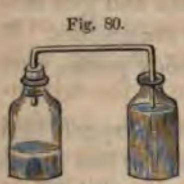
Sulphur has also another resemblance to oxygen, that of combining with other bodies in greater or less quantities, according to circumstances. The quantities here also are always fixed and unchangeable for every individual combination (stochiometry). In the simple gray sulphuret of iron, 100 ounces of iron are always united with 57½ ounces of sulphur; in the yellow iron pyrites 100 ounces of iron always unite with 115 ounces of sulphur (degrees of sulphuration); if more sulphur is present, it remains uncombined. The degrees of oxidation are distinguished by the terms *protoxides*, *sesquioxides*, and *peroxides;* in the combinations of sulphur, when the sulphur predominates, they are called *sesquisulphurets* and *persulphurets;* and when the sulphur is not in excess, they are called *protosulphurets;* and in the latter term, when there is a deficiency of sulphur, the syllable *sub* is substituted for *proto*.

The chemical symbol for sulphur is = S. Protosulphuret of iron is expressed by the symbol $Fe\,S$; persulphuret of iron, by $Fe\,S_2$. Fe, the first two letters of the Latin word *ferrum*, is the symbol for iron.

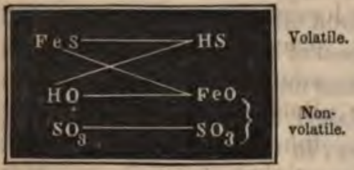
SULPHURETTED HYDROGEN, OR HYDROSULPHURIC ACID ($H\,S$).

132. *Experiment.* — Put half an ounce of protosulphuret of iron ($Fe\,S$) and half an ounce of diluted sulphuric acid (§ 84) into a two-ounce flask, and quickly stop the flask with a cork, to which a bent glass tube is adapted.

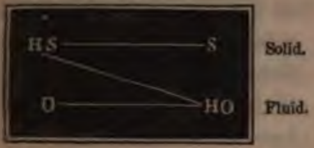
Fig. 80.



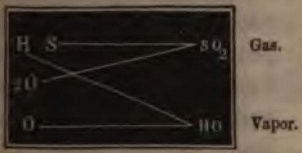
Introduce the longer limb of the tube into a bottle filled with cold water. The atmospheric air contained in the flask and tube first passes over, followed by a very offensive gas, which dissolves in the water, to which it likewise imparts its fetid odor of rotten eggs. This gas is called *sulphuretted hydrogen.* The decomposition in this case is similar to that effected in the preparation of hydrogen from iron (§ 84). Water is decomposed, its oxygen unites with the iron, forming protoxide of iron, and this unites with the sulphuric acid, forming green vitriol; but the hydrogen of the water escapes, and takes with it as a companion the sulphur contained in the sulphuret of iron. The light, gaseous hydrogen possesses in a great degree the power of rendering other bodies aeriform on uniting with them, even those which are not volatile or have but a slight tendency to become so; just as an eloquent speaker can communicate his enthusiasm to a heavy and indifferent audience. Even carbon, which has never been liquefied, is converted into a light gas when combined with hydrogen, as in illuminating gas.



When the disengagement of the gas ceases, add some diluted sulphuric acid that the gas may again be generated. The water is known to be saturated with the gas, when, on shaking the bottle, the finger by which the opening is closed is no longer sucked in, or, more correctly speaking, pressed in; one measure of water contains two and a half measures of gas in a saturated solution. It is put up in small well-stoppered bottles, which are labelled *Hydrosulphuric Acid.* If air be admitted, the solution becomes turbid, owing to the oxygen of the air uniting with the hydrogen of the sulphuretted hydrogen, forming water, and the consequent liberation of the sulphur as a fine powder.



If, during the evolution of the gas, the bottle of water be removed, the gas issuing from the tube can be ignited by a match; it burns with a blue flame, and its nauseous odor is no longer perceptible, but is replaced by the well-known odor of burning sulphur. Both constituents unite with the oxygen of the air, the sulphur forming sulphurous acid, and the hydrogen water.

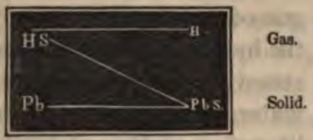


The inhalation of sulphuretted hydrogen is *detrimental* to health; hence precautions should be taken to avoid it. When experimenting with it, it is best to do so where there is a free circulation of air. A cloth moistened with a little alcohol, and held before the mouth, is likewise a good protection.

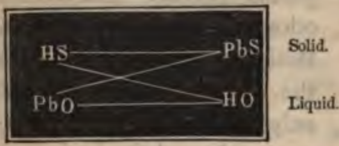
Sulphuretted hydrogen turns blue litmus-paper red; it also combines with many bases, and hence it is an acid. It has also been called *Hydrothionic Acid*, from two Greek words, signifying water and sulphur. Thus, oxygen is not essential to the acidity of a compound, since hydrogen also possesses this acidifying principle; but the latter produces acids with but few elements, whilst oxygen does with numerous elements.

133. *Experiments with Sulphuretted-Hydrogen Water.*

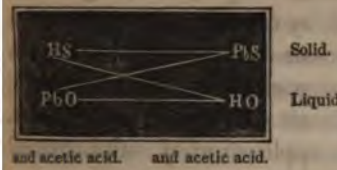
Experiment a. — Drop some sulphuretted-hydrogen water upon a bright silver or copper coin, and upon a piece of lead and iron; the first three metals tarnish quickly, and finally become black; they combine with the sulphur, forming a dark *sulphur* metal, whilst the hydrogen escapes; the iron, on the contrary, undergoes no change. Pb is the symbol for lead, plumbum.



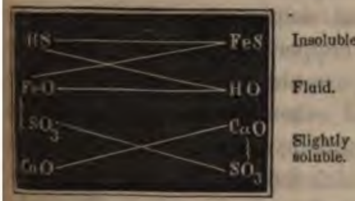
Experiment b. — Put into one test-tube a small portion of litharge, into another some ignited iron-rust, and pour upon them liquid hydrosulphuric acid; the yellow litharge, oxide of lead, becomes immediately black, an exchange of elements takes place, the hydrosulphuric acid gives its sulphur to the lead of the litharge, and receives in return the oxygen of the latter. Accordingly, *sulphuret of lead* and water are formed, and the offensive odor disappears. In the vessel containing the iron-rust neither the color nor the smell is affected, — a proof that no chemical change has taken place.



Experiment c. — Repeat the same experiment with a small crystal of sugar of lead instead of the litharge, and some green vitriol instead of the iron-rust, together with a few drops of vinegar, these salts having been previously dissolved in a large quantity of water; the result will be the same as in the former experiment. Sugar of lead is the acetate of the oxide of lead; the salt of lead is converted into sulphuret of lead, which subsides sooner or later as a black precipitate. When this solution is extremely diluted, it is only colored brown. The acetic acid is set free, and remains in solution.



Experiment d.—If some lime-water or soda be added to the vitriol solution, which in the former experiment remained unaffected by the addition of sulphuretted hydrogen, it will immediately assume a deep black color. The added base effects, what otherwise would not have occurred, a combination of the sulphur with the iron, and for this reason, that the new base itself unites with the sulphuric acid of the green vitriol. The sulphuric acid has so great an affinity for the protoxide of iron, that it will not part with it unless in the presence of a stronger base, which the lime and soda have proved themselves to be. Lime is oxide of calcium, and is represented by the symbol Ca O.



From these experiments the following rules are derived:—

a.) Sulphur in its moist state, and when dissolved in water, has a very great affinity for metals, and converts metals, metallic oxides, and salts into sulphur metals.

b.) Most of the metallic sulphurets are *insoluble* in water; hence sulphuretted hydrogen is peculiarly adapted for precipitating metals from their solution, so that they can be separated and collected by filtration. If sulphuretted hydrogen be passed through a solution of acetate of copper, sulphuret of copper will be precipitated, and can be separated by filtration from the acid. All the sulphurets do not possess a black color; sulphuret of antimony has an orange-red color, sulphuret of arsenic a yellow, and sulphuret of zinc a white color. On this is partly based the application of sulphuretted hydrogen as a re-agent, that is, as a means of detecting many metals. Wine containing lead is blackened by hydrosulphuric acid, which for this reason is called *Hahnemann's wine-test.*

c.) Many metals are precipitated from their solutions by the addition merely of sulphuretted hydrogen, as sulphurets; for example, copper, silver, gold, lead, mercury, tin, antimony, and arsenic (these are called *electro-negative* bodies); and others are not precipitated until a stronger base is added; for example, iron, zinc, manganese, cobalt, and nickel (these are called *electro-positive*). Sulphuretted hydrogen may accordingly be used to separate one class of metals from another; it is therefore an important means of separation in analytical chemistry.

134. Hydrosulphuric acid has, as already mentioned, the formula $H\,S$, which indicates that it is composed of one atom of hydrogen and one of sulphur, and the similarity of this formula to that of water, $H\,O$, is apparent.

135. It is well known, that during the decomposition of *animal substances,* blood, flesh, hair, urine, excrements, white and yolk of eggs, &c., a putrid odor is evolved; this is owing to sulphuretted hydrogen, which is formed from the small quantity of sulphur contained in many animal substances, and from the hydrogen of the water, and is diffused in a gaseous form in the air. It will no longer appear strange that copper vessels, if exposed to

such an atmosphere, will tarnish, become brown, and indeed, finally, black.

136. Sulphur is also met with in *vegetable* substances, particularly in the leguminous plants, — peas, beans, lentils, &c., — and in some acrid plants, such as mustard and horseradish. If these be heaped together in a pile when moist, they will, on decaying, likewise evolve sulphuretted hydrogen.

137. Finally, it remains to be stated that this gas occurs also in some *mineral waters*, as may be recognized by the smell and taste. Many of these springs, for instance, the celebrated springs of Aix-la-Chapelle, are resorted to by invalids, and are called *sulphur springs*. A rotten wooden pump or log would convert an otherwise potable water, if it should contain gypsum, into a nauseous sulphuretted water; by purifying the well and introducing a new log, the water may be rendered completely odorless and good.

SELENIUM (Se).

Selenium is an element which has a great resemblance to sulphur. It is of rare occurrence, and is contained in the red matter deposited from certain varieties of sulphuric acid, especially after the acid has been diluted with water.

PHOSPHORUS (P).

At. Wt. = 400. — Sp. Gr. = 1.75.

138. Great care is required in experimenting with phosphorus, that it does not take fire at an unseasonable moment, as it continues burning with the greatest violence, and might occasion dangerous wounds. It may catch fire even when lying upon blotting paper, par-

ticularly in summer-time, or by the heat of the finger. Hence it must be kept, and also cut, under water. On being taken from the water it should be held by a pair of forceps, or be stuck on the point of a knife. Prudence also would dictate to experiment with small quantities only at a time, and to have a vessel of water in readiness, in which it may be quenched in case it should catch fire.

139. Phosphorus is, in its properties, closely allied to sulphur, but it has an incomparably more irritable temperament. Sulphur may be regarded as the phlegmatic brother of phosphorus. Phosphorus, like sulphur, melts, boils, evaporates, and burns, but far more easily and rapidly. In winter it is brittle, in summer flexible as wax. When pure and freshly prepared it is colorless, transparent, and amorphous, but after a time it becomes yellow, and coated over with a hydrated white crust.

Phosphorus is insoluble in water, but soluble in ether, alcohol, sulphuret of carbon, and oils.

140. *Experiments with Phosphorus.*

Experiment a.— Put into a small flask, first a quarter of an ounce of ether, then a piece of phosphorus, of the size of a pea. Cork the flask and let it stand some days, frequently shaking it. Decant the liquid; it contains in solution about one grain of phosphorus, and will serve for the following experiments.

Experiment b.— Pour some drops of this solution upon the hand, and rub them quickly together; the ether will evaporate in a few moments, but the phosphorus will remain upon the hands in a state of minutest division. The more finely it is divided, so much the more easily does it combine with the oxygen of the air. During this combination it diffuses a white smoke and a *strong light* (it phosphoresces), causing the hands to shine in the dark; hence its name, *phosphorus*, from φῶς, *light*, and φέρειν, *to carry*. On rubbing the hands this light becomes more vivid, as a fresh surface of phosphorus is thus continually presented to the oxygen of the air. The heat thus evolved is too feeble to occasion ignition. This oxidation, taking place at a low temperature, is called *slow combustion*. The hands, during the phosphorescence, have an alliaceous smell, and impart at the same time a sour taste to the tongue, as the combination of the oxygen with the phosphorus is an acid; it is called *phosphorous acid*, and consists of one atom of phosphorus and three atoms of oxygen. When a larger quantity of acid is required, put a stick of phosphorus into a flask, and let it remain in the cellar until the phosphorus is converted into a colorless acid liquid. A portion of the phosphorous acid thus prepared takes up yet more oxygen and becomes phosphoric acid; accordingly, the liquid thus obtained is a mixture of these two acids.

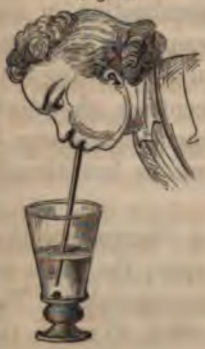
Experiment c. — Moisten a lump of sugar with the solution of phosphorus, and throw it into hot water. The heat of the latter volatilizes the ether and the phosphorus, both of which rise to the surface of the water and there inflame spontaneously on coming in contact with the oxygen of the air. The combustion in this case is brisk and complete. The phosphorus takes up a larger quantity of oxygen, one atom of it uniting with five of oxygen; there is formed a scentless *phosphoric acid*, which is always generated when phosphorus is completely burnt, that is, with a flame, as has already been explained.

Experiment d. — Pour some of the ethereal solution of phosphorus upon fine blotting-paper; the latter *ignites spontaneously* after the ether has evaporated. The more minutely the phosphorus is divided, so much the more readily it begins to burn.

Experiment e.—Put a piece of phosphorus of the size of a pea on blotting-paper, and sprinkle over it some soot or pulverized charcoal; it melts after a while, and spontaneously *inflames*. The finely pulverized charcoal causes this combustion, owing to its porosity. It eagerly absorbs oxygen from the air, imparts it again to the phosphorus, and, being also a non-conductor, the cooling of it is prevented.

141. Phosphorus is also *easily ignited by friction*, and is, for this reason, employed in the manufacture of friction-matches. The combustible mass consists of phosphorus intimately kneaded with mucilage or glue. But as the mass, becoming hard on drying, would prevent the admission of air to the phosphorus, there must be added some substance rich in oxygen, as black oxide of manganese, nitre, or red-lead, from which the phosphorus can abstract the oxygen necessary for its ignition. A temperature of 65–70° C. is requisite for kindling matches (§ 113); in this case the temperature is caused by friction. The coating of the match is thus broken and kindled, and the continued burning is now maintained by the oxygen of the air.

Fig. 81.

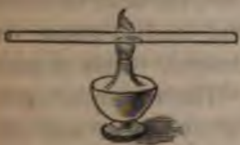


142. *Experiment.* — Put a piece of phosphorus, of the size of a pea, into a wine-glass, and pour hot water upon it, until the glass is half filled; the phosphorus melts, but does not ignite, as access of air is prevented by the water. But if air be carefully blown by the mouth through a long glass tube upon the bottom of the wine-glass, a *combustion* will ensue which is visible, espe-

cially in the dark. The phosphorus enters at once into oxidation, but with the formation of a lower compound; it swims as a red-hot powder in the liquid, and is called *oxide of phosphorus*, containing for every two atoms of phosphorus only one atom of oxygen.

143. *Experiment.*—We obtain the same combination by gently heating a piece of phosphorus of the size of a pea, placed in the middle of a glass tube, about twelve inches long. When ignition commences, remove the lamp. While the tube is held horizontally, the combustion is feeble and imperfect, because the heavy smoke, consisting of phosphoric and phosphorous acids, passing off slowly, allows the admission of only a small quantity of air. Some red oxide of phosphorus is also deposited on the upper part of the tube. But the combustion becomes at once more vivid by inclining the tube, and when the tube is held perpendicularly it is complete, as then the draught of air is most powerful. In this way phosphorus may be oxidized to either degree required; it must be slowly burnt to form phosphorous acid, imperfectly to form oxide of phosphorus, and completely to form phosphoric acid The experiment is also well adapted for illustrating the principle of draughts in chimneys, &c. (§ 111).

Fig. 82.



144. Phosphorus was formerly obtained from urine, and is now universally prepared from bones. Bones consist of gelatine, lime, and phosphoric acid ($P O_5$).

The *gelatine* is removed by calcining the bones. It is burnt.

The *lime* is removed by sulphuric acid. Sulphate of lime is formed.

Phosphoric acid. The *oxgyen* (O_5) is expelled by igniting the bones with charcoal (carbonic acid gas is disengaged).
Phosphorus (P) remains behind.

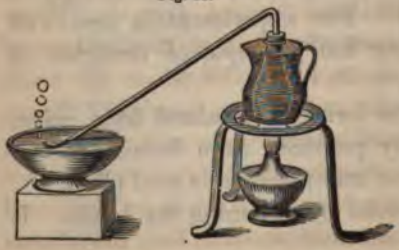
As phosphorus is volatile and highly inflammable, the phosphoric acid and charcoal are heated in a close vessel, commonly in an earthen retort, the beak of which dips under water contained in the basin, where the vapor of phosphorus is to be condensed. This process is accordingly one of distillation. The carbonic oxide, together with some phosphuretted hydrogen and carburetted hydrogen gas, escape through the water.

Charcoal, at a glowing heat, has the power of abstracting oxygen from almost all acids and bases, as in this case from phosphorus, or, chemically speaking, to *deoxidate* or *reduce* them; thus carbonic oxide (CO), which escapes, is formed from carbon and oxygen. Almost all metals are obtained from native metallic oxides or ores, by heating them with charcoal.

PHOSPHURETTED HYDROGEN (PH_3).

145. *Experiment.* — Put into an ounce flask a quarter of an ounce of slaked lime, and a piece of phosphorus the size of a pea, fill it up to the neck with water, and place it in a small vessel containing a strong

Fig. 53.



solution of salt, prepared by adding half an ounce of salt to one ounce and a half of water. Fit to the flask a bent glass tube, one end of which is made to dip into a basin of water; heat the salt water to boiling, and a gas will be evolved, which, as it issues from the tube and comes in contact with the air, *inflames spontaneously.* This gas is called *phosphuretted hydrogen,* and consists of several combinations of phosphorus and hydrogen, chiefly of PH_3. If you collect it in a small jar filled with water, it immediately ignites upon the admission of air. Both the phosphorus and the hydrogen combine with the oxygen of the air, and there results phosphoric acid (PO_5) and water (HO). The first rises as a white smoke, and the gas, as it issues in separate bubbles from the water, takes the form of a wreath. Phosphuretted hydrogen, when unburnt, emits the smell of garlic.

146. In the preparation of sulphuretted hydrogen (§ 132), the iron deprived the water of its oxygen, and the sulphur took the liberated hydrogen. What these two substances together accomplished, phosphorus can effect alone; it abstracts from the water both its oxygen and hydrogen, and it divides itself between the elements of the water. Phosphorus forms with oxygen two acids, phosphoric and hypophosphorous acids, which remain behind; but it forms with hydrogen a volatile gaseous combination, which escapes. Phosphorus, however, can only effect this in the presence of a strong base, for instance, lime, with which the acids composed of phosphorus and oxygen combine. Thus, lime does not directly aid in the decomposition of water, but it encourages the phosphorus to exert more power and activity. The lime would gladly have combined with acids, but there *are none present*; they may, how-

ever, be formed, if the phosphorus abstracts the oxygen from the water. This does take place, and we can say the lime urges on the phosphorus,—disposes it to decompose the water, in order, as it were, to satisfy its own eagerness to unite with an acid. Thus is defined the name which this kind of affinity has received; it is called *disposing affinity*. This term expresses an affinity, an eager desire to combine with a body not yet existing, but which body may be formed from the elements present, and which is in reality formed in consequence of this desire.

147. If we now reflect upon the processes of preparing hydrogen (§ 84) and sulphuretted hydrogen (§ 132), we shall see that in both of these instances a disposing affinity is also exerted. But the impelling body, in these instances, is an acid,—the powerful sulphuric acid. This acid has a strong desire to unite with a base, and it urges the iron to convert itself into a base, which is readily accomplished when the iron combines with the oxygen of the water. The other element of the water is thereby set free, and escapes as a gas, in the first case alone, in the second accompanied by sulphur, which the iron releases at the moment when it combines with the oxygen, for which it has a preference.

148. It may, perhaps, be asked why the sulphuric acid did not immediately combine with the metallic iron, or the lime with the phosphorus; this could not take place, as *simple substances, with but few exceptions, combine only with simple ones, and compound only with compound substances.* Hence the compound, sulphuric acid, cannot combine with the simple element, iron, but can combine with the compound, protoxide of iron. Neither can the compound, lime, enter into combination

with simple phosphorus; but it will do so immediately, when phosphorus, by combining with oxygen, becomes a compound body.

149. In the last experiment, the flask was placed in salt water, in order to guard against the ignition of the phosphorus, in case the flask should accidentally break. Salt water, at the strength specified, will not boil under 109° C.; consequently the boiling in the flask is more active than if it had been placed in pure water, the temperature of which, under ordinary pressure, can only be raised to 100° C. The apparatus for heating substances by means of hot water or saline solutions, is called a *water* or *saline bath*. By such contrivances extracts are evaporated, and substances dried, which, at a stronger heat, would easily burn, or be otherwise decomposed.

Phosphorus and sulphur are especially characterized by their great inflammability; hence they may be called *pyrogens*, or *fire-generators.*

RETROSPECT OF THE PYROGENS (SULPHUR AND PHOSPHORUS).

1. Simple bodies combine only with simple bodies, compound only with compound bodies.

2. In order that two bodies may act chemically on each other, one of them must, as a general rule, be liquid or gaseous.

3. When a body is suddenly precipitated from its liquid or gaseous state, as a solid, it is then obtained as a fine dust (milk of sulphur and flowers of sulphur).

4. All finely divided *and porous* bodies eagerly ab-

sorb gases, and condense them within their pores; in many cases this is done so powerfully as to force the gases into chemical combination (spongy platinum, charcoal).

5. An *incomplete combustion* or oxidation takes place when the supply of air is deficient; a *slow combustion*, when substances combine with oxygen at the common temperatures; but a *complete and rapid combustion*, when the union takes place at a high temperature, and with an abundant and constant supply of air. In the two former cases, lower degrees of oxidation are formed, and in the latter, higher degrees of oxidation.

6. In chemical reactions *the right of the strongest prevails;* a stronger chemical substance can expel a weaker from its combination, and replace it. This is called decomposition by *simple elective affinity.*

7. *Decomposition by double affinity* takes place when two combinations mutually exchange elements.

8. If a single or double elective affinity is caused by the presence of a third body, commonly a strong acid or a strong base, it is called *disposing affinity.*

9. *Deoxidate*, the opposite of *oxidate*, is a term applied to the depriving compounds of their oxygen.

10. In order to detect a chemical substance, and to separate it from others, the solution of it is mixed with *reagents*, that is, with such bodies as form with it an insoluble compound (precipitate), or change its color, smell, &c.; such changes are called *reactions.*

11. *Taste* is perceived only in soluble bodies, *odor* only in volatile ones.

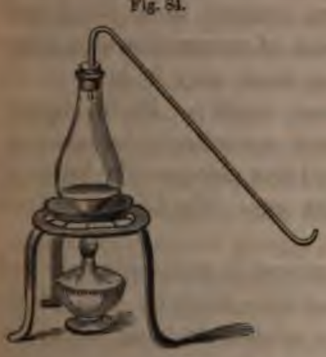
THIRD GROUP OF METALLOIDS: HALOGENS.

CHLORINE (Cl).

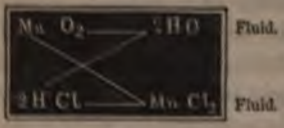
At. Wt. = 443. — Sp. Gr. = 2.5.

150. *Experiment.* — Pour one ounce and a half of muriatic acid upon a quarter of an ounce of finely powdered black oxide of manganese, and heat it gradually in a flask, to which is adapted a bent glass tube; a yellowish-green gas is disengaged, which is collected by a process already described. This gas is called *chlorine* (from χλωρός, *green*), because it has a greenish color. Fill with it several six-ounce bottles of white glass, and cork them up. Fill, likewise, a bottle with two thirds of chlorine and one third of water, and shake it up; suction is exerted upon a finger which closes the mouth of it, — a proof that a vacuum has been occasioned. If the finger be removed, the air rushes in at once. This vacuum was caused by the chlorine having been dissolved in the water, which may be inferred also from the disappearance of the yellow color in the vacant space of the bottle. One measure of water dissolves two measures of chlorine. This solution is called *chlorine water.*

Fig. 84.



Muriatic acid, which is usually prepared from common salt, is a combination of chlorine and hydrogen, and belongs to the class of *hydrogen* acids; if it be deprived of the hydrogen, the chlorine is set free. This is done in the following manner. When muriatic acid is added to hyperoxide of manganese ($Mn\ O_2$), the oxygen of the manganese takes from the muriatic acid its hydrogen, and *water* is formed, but simultaneously also hyperchloride of manganese ($Mn\ Cl_2$), from the liberated manganese and chlorine. The hyperchloride of manganese, however, loses at a very gentle heat half of its chlorine, just as the oxygen escaped from the hyperoxide of manganese at a glowing heat, only it loses it far more readily. From hyperchloride of manganese, there is accordingly formed protochloride of manganese and free chlorine, the latter of which escapes as a yellowish gas. $Mn\ Cl_2$ is resolved into $Mn\ Cl$ and Cl.



If the oxygen of the manganese is previously expelled by heat, and then conducted into muriatic acid, it no longer possesses the power of withdrawing from the acid its hydrogen, and consequently no chlorine will be evolved. Oxygen has this power only at the very moment when it is separating from its combination with another body, that is, in its *nascent state*. When actually liberated, it has far less inclination to abandon its freedom. This peculiarity appertains to other elements, and it is often taken advantage of to force into combination such bodies as have but slight affinity for other bodies, and which combination could not have been effected in a direct way.

Chlorine is not only obtained from manganese, but from all bodies which part easily with their oxygen, as, for instance, chlorate of potassa, red lead, &c., by *heating them* with muriatic acid.

151. Muriatic acid derives its chlorine from common salt, more than half of which consists of chlorine; consequently, this gas may be also obtained from salt by mixing three quarters of an ounce of it with half an ounce of black oxide of manganese, two ounces of sulphuric acid, and one ounce of water, and heating them; by adding sulphuric acid to the salt, muriatic acid is formed, and set free, and this is decomposed by manganese, in the way already mentioned.

Chlorine acts as a *poison* on being inhaled; hence, *care must be taken not to inhale it* while operating with it. For greater security pour some drops of alcohol and ammonia upon a cloth and wave it frequently in the air; the chlorine contained in the air will then be so altered, that it will lose its injurious properties.

152. *Experiments with Chlorine.*

Experiment a. — In order to recognize the odor of chlorine, smell cautiously chlorine water (but not the gas); the chlorine water may be tasted also without danger. The smell of chlorine is peculiarly pungent and suffocating, and it has a harsh, styptic taste.

Experiment b. — If a flask containing chlorine gas be exposed to the air, no diminution of chlorine will be perceptible; but if the flask be inverted it will contain in a short time only atmospheric air. Chlorine is two and a half times *heavier* than common air, and its specific gravity is 2.5.

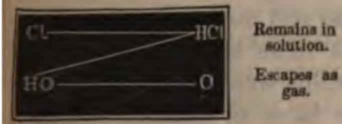
Experiment c. — Introduce a piece of litmus-paper into chlorine gas, and it becomes white; pour chlorine water upon red wine, or ink, and both the liquids will lose their color. *Chlorine bleaches and destroys all colors derived from the animal or vegetable kingdom.* In consequence of this property, chlorine has become a most important agent in bleaching; and linen, cotton, paper, and other

materials, may now be rendered perfectly white by i
a few hours; while, by the old method of laying th
on the grass in the sun, weeks, and even months, w
required for effecting it. This method of bleach
is called *quick bleaching*, the other is called *gr*
bleaching. The modern method is very excellent,
does not in the least injure the strength of the fab
provided all the chlorine be completely removed ag
after the bleaching is finished, which is not so ea
done as many bleachers suppose. If this precaution
not observed, or if the chlorine water is too strong
in excess, then indeed, after the color is destroyed,
fibres of the yarn or fabric itself will be attacked. T
fault is not to be attributed to the chlorine, but rat
to the injudicious application of it. A salt has lat
been introduced into commerce, under the name
antichlorine, by means of which, if any chlorine sho
happen to remain in the bleached materials, they w
not be in the slightest degree injured by it. As t
health of the laborers is endangered by the use of ch
rine gas or chlorine water, *chloride of lime* is n
substituted, a salt in which chlorine is chemically co
bined, but from which it may be easily disengaged
mere exposure to the air.

Experiment d.— Apply chlorine water to decayi
and nauseous substances (water from flower-pots, m
nure, rotten eggs, &c.); the bad odor will at once
tirely vanish. Thus it not only *decomposes* colors, b
also the *volatile combinations* formed during decay, a
which occasion disagreeable odors. It acts in a simi
manner also upon morbific matter (malaria, miasm
which, being diffused in the air or attached to cloth
and beds, may communicate disease. Chlorine is ther
fore a powerful *disinfecting agent*, and is used for pu

fying all morbid matter and infected atmospheres, and for arresting the decay of organic substances. Musty casks may also be purified by washing them first with chlorine water, and then with some milk of lime. Mouldy cellars, in which milk or beer cannot be kept without turning sour, are again rendered serviceable for a long time by fumigating them with chlorine gas, or by washing them with chlorine water, or a solution of chloride of lime.

Experiment e. — Fill a small flask with chlorine water, and invert it in a vessel filled with water; if this is put away in a dark place, it remains unchanged; but if it is exposed to the sun, a colorless gas will collect in the upper part of the flask, in which a glowing taper will inflame; this gas is oxygen. After some days the water will entirely lose its chlorine odor, and will have acquired a sour taste, and instead of bleaching blue litmus-paper, it will redden it. Three elements only were present, the constituents of water and chlorine; thus it is obvious, that the chlorine must have united with the hydrogen of the water to form muriatic acid, the oxygen being set free. Chlorine had here the choice between hydrogen and oxygen; it chose the former; it has, consequently, *a greater affinity for hydrogen* than for oxygen. This affords another example of simple elective affinity. The chlorine water should therefore be protected from the light, and this can be most conveniently done by pasting black paper round the vessel containing it.

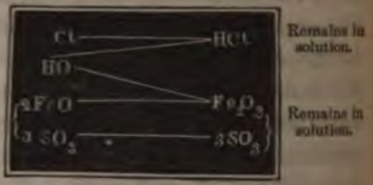


The bleaching and disinfecting power of chlorine is now easily explained by its strong affinity for hydrogen.

All animal and vegetable substances contain hydrogen, which is taken from them by chlorine. But if a single chemical pillar falls, the whole chemical structure tumbles with it. By the abstraction of the hydrogen, the coloring matter becomes colorless, the odorous principles scentless, the morbific matter innoxious, insoluble substances are very frequently rendered soluble, &c.

Experiment f. — Dissolve in a test-tube a small quantity of green vitriol (sulphate of iron), in cold water, and add to the solution a few drops of sulphuric acid; then, some chlorine water; the solution will immediately assume a yellow color. In this case, also, the water is decomposed; the hydrogen passes to the chlorine, but the oxygen is not liberated, since it here meets with a body which already contains oxygen, but which is capable of receiving still more, namely, protoxide of iron. This becomes more highly oxidized, and the yellow liquid now contains sulphate of sesquioxide of iron. Consequently we have in chlorine water a powerful *oxidizing agent*, by means of which we can easily convert protoxide salts into salts of the sesquioxide or peroxide.

Fig. 55.



Experiment g. — Put into chlorine water some *pure* gold-leaf; it will soon disappear, as the simple element chlorine combines with the simple element gold. The *combination* is called chloride of gold; it is soluble in water. Chlorine has a very *great tendency to combine with the metals.* These combinations comport themselves like salts; they are called *chlorine metals*, and most of them are soluble in water.

Experiment h. — Pour into a vessel filled with chlorine gas a little metallic antimony, in fine powder; it will fall in a glowing state to the bottom, as though it were a shower of fire. The fire is caused by the violent combination of the chlorine with the antimony. The white smoke which fills the flask is the new combination formed, viz. chloride of antimony. If a fine brass wire, on which a piece of tinsel has been fastened, be introduced into chlorine gas, the wire will burn with a vivid combustion, and with the emission of sparks. Here combustion means the same as a combination with chlorine. Brass consists of zinc and copper; accordingly, chlorides of zinc and copper are formed. Both dissolve in water, and the chloride of copper imparts to the solution a green tinge.

Experiment i. — Place in this solution a polished knife-blade; in a short time it will be covered with a coating of the red metal, copper. The iron possesses a still greater affinity for chlorine than copper does, and, as in chemical reactions the right of the strongest prevails, so the iron seizes the chlorine, and the copper is deposited in the metallic state. This method is frequently employed for precipitating a metal from its solution. Polished steel is, accordingly, *a reagent for copper*, and by means of it we can ascertain, very simply and accurately, whether copper is present in pickled cucumbers, or preserved fruit, which may have been carelessly prepared in copper vessels.

153. *Experiment.* — If a piece of sodium of the size of a pea is thrown into a cup containing chlorine water,

it will move rapidly round, just as in common water, with a hissing noise, and finally disappear; but if a sufficient quantity of the chlorine was present, the liquid will not afterwards give a basic reaction, as in the experiment in § 67; neither will it have an alkaline, but a saline taste. If allowed to evaporate gradually over a warm stove, small cubic crystals remain behind, the constituents of which are chlorine and sodium. Thus, from these two elements a *salt* has been formed, familiarly known as *common salt.*

154. Chlorine, like oxygen and sulphur, unites in several proportions with other substances. Thus, there are different chlorides, as well as different oxides and sulphides. The combinations containing smaller quantities of chlorine are called *protochlorides;* those containing larger quantities are called *perchlorides.*

IODINE (I).

At. Wt. = 1586. — Sp. Gr. = 5.

155. Iodine is a solid body, somewhat resembling plumbago; it smells a little like chlorine, has a pungent taste, and stains the skin brown.

Experiment. — Put 24 grains of iodine into a flask, and pour over them half an ounce of strong alcohol; if the iodine is pure it will entirely *dissolve.* This dark brown solution is called *tincture of iodine.* Water dissolves only a trace of iodine, but yet is rendered yellow by it.

Experiment. — Put a little iodine upon a knife, and hold it over the flame of a lamp; the iodine melts, and is afterwards converted into a *violet-colored gas, — iodine fumes.* As the iodine fumes are nearly nine times heavier than common air, they sink in it. Iodine owes its name to the color of its fumes, the Greek word ἰώδης meaning *violet-colored.* The fumes appear more beautiful when the iodine is heated in a small flask. After cooling, the walls of the flask become lined with small brilliant crystals of solid iodine, affording an example that regular crystals may also be formed when bodies pass from the aeriform into the solid state.

Experiment. — Boil one grain of starch in a test-tube with one drachm of water, and add to the thin paste thus obtained a few drops of tincture of iodine; *the iodine combines with the starch; the combination is of a deep blue color.* The blue color disappears on boiling, but returns again on cooling. If one drop of the starch paste is mixed with one quart of water, even at this extreme dilution, the iodine tincture will impart to it a violet tinge. Consequently, it is an exceedingly sensitive reagent for detecting starch, and starch, on the other hand, for detecting iodine. If a little iodine tincture is dropped upon flour, potatoes, &c., the presence of starch in these substances will at once be indicated.

BROMINE (Br).

At. Wt. = 1000. — Sp. Gr. = 3.

156. Bromine is a deep brownish-red, heavy, and very volatile liquid. Its name is derived from the Greek word βρῶμος, signifying a strong odor. Bromine, at common temperatures, emits yellowish-red fumes, which have a suffocating and offensive odor, similar to that of chlorine. It produces a yellow color with starch.

Iodine and bromine have, in their relations to other bodies, *the greatest similarity to chlorine.* Like chlorine, they possess a strong affinity for hydrogen, and form with it acids; they also combine with the metals forming protoiodides and periodides, protobromides and perbromides, which comport like salts. If a polished silver plate be held over the fumes of iodine and bromine, it is colored, first yellow, then violet, and then blue, owing to these vapors combining with the silver. This film of iodide and bromide of silver is decomposed almost instantaneously in the light, slowly in the shade, and not at all in the dark. On this property is founded the *Daguerreotype* process. Iodine and bromine are also used in medicine for dispelling tumors and goitres, and in the treatment of scrofula, &c.

Both of these two substances are faithful companions of chlorine; wherever common salt occurs, whether in the earth, the sea, or mineral springs, small quantities of them are present, not in a free state, however, but combined with metals. The different sea-weeds attract these combinations from the sea-water, and from these sea-weeds iodine and bromine are extracted. Both of these bodies have poisonous properties.

FLUORINE (Fl).

At. Wt. = 235.

Fluorine is likewise an element having similar properties to chlorine, but it is hardly known in its isolated state. The mineral known as fluor-spar, crystallizing in cubes, consists of fluorine and calcium.

CYANOGEN (C_2N or Cy).

At. Wt. = 325. — Sp. Gr. = 1.8.

157. *Prussian-blue*, universally used as a pigment, *consists of iron*, carbon, and nitrogen. But both the two lat-

er substances are so closely combined with each other, hat they may be regarded as one. The most striking hing in this combination is, that, although a compound, it combines with the elements *exactly in the ame manner as though it were itself an element.* For this reason, under the name *cyanogen*, it is here included among the elements. It forms an exception to the previously mentioned rule, that simple bodies can only combine with simple, and compound only with compound bodies. Cyanogen comports towards other bodies in *a manner similar to that of chlorine, iodine, bromine, and fluorine;* it is gaseous, and, like these, forms with hydrogen an acid, the poisonous prussic acid, and, like them, also unites with metals, forming protocyanides and percyanides. The cyanogen compounds have likewise the character of salts. The combination of cyanogen with iron, as already stated, is of a beautiful blue color, and hence the name *cyanogen*, from the Greek word *κύανος*, *blue.*

The five metalloids, chlorine, iodine, bromine, fluorine, and cyanogen, are characterized as follows:—

1. They have a far greater affinity for hydrogen than for oxygen. They combine with the latter only on compulsion (oxygen acids).
2. Their combinations with hydrogen are acids (hydrogen acids).
3. Their combinations with the metals are salts. These salts are called *haloid salts*, to distinguish them from the common or *oxygen salts*, which consist of an acid and a base.

On account of this latter peculiarity, these elements have been called *halogens*, or *salt producers.*

RETROSPECT OF THE HALOGENS (CHLORINE, IODINE, BROMINE, FLUORINE, AND CYANOGEN).

1. Crystals may be formed,—1st, from a *solution*, either by cooling (saltpetre), or by evaporation (common salt); 2d, from a *molten* fluid, by congelation (sulphur); and 3d, from *vapor*, when it becomes solid immediately on cooling (snow, iodine).

2. The crystallized or regularly formed bodies are the reverse of the *amorphous* bodies, in which no definite form is to be perceived (vitreous and pulverulent bodies). Many bodies can assume two, or even several, different forms, and are called dimorphous or polymorphous bodies (coal, sulphur).

3. Water can dissolve, not only solid, but gaseous bodies; for instance, chlorine, sulphuretted hydrogen, &c., and the more of them the colder it is.

4. Not only heat, but light also, may effect or destroy chemical combinations.

5. A body has a greater inclination to combine with another body at the very moment when it is separated from a combination (nascent state).

6. There are, also, by way of exception, compound bodies, which, just as if they were chemical elements, can combine with simple bodies (cyanogen).

FOURTH GROUP OF METALLOIDS: HYALOGENS.

BORON (B),

At. Wt. = 136, and

SILICON (S).

At. Wt. = 277.

158. Both of these substances occur, in nature, only *in combination* with oxygen; boron but seldom, as in

boracic acid or borax; and silicon very abundantly, as in sand, quartz, and almost all other stones. The word *silicon* is derived from the Latin *silex*, flint; hence its symbol, Si. Boracic and silicic acids form, with many bases, amorphous salts (glass, slag, glazing); for this reason, boron and silicon may be called *hyalogens* or *glass producers.*

RETROSPECT OF THE NON-METALLIC BODIES, OR METALLOIDS.

1. The thirteen substances now treated of may be called the *non-metallic bodies*, or *metalloids*, because they do not possess a metallic appearance.

2. Heat and electricity pass through them very slowly; they are *bad conductors* of heat and electricity. The metals, on the contrary, which give rapid transit to those forces, are good conductors.

3. On decomposition by *galvanism*, the metalloids always separate at the positive pole (the zinc side), and the metals at the negative pole. As the positive pole only attracts bodies endowed with the opposite or negative electricity, and the negative pole only those endowed with positive electricity, so the metalloids are called *electro-negative* bodies and the metals *electro-positive* bodies.

4. Almost all the metalloids combine with *hydrogen*, but, as a general rule, the metals do not. Some of the hydrogen combinations have acid properties (*hydrogen acids*).

5. In the same manner, the metalloids combine with oxygen, forming acid-oxides or *oxygen acids.* The metals also combine with oxygen, but forming mostly oxides or *bases.*

6. The following are the states of aggregation of the metalloids at the ordinary temperature: —

7 metalloids, solid: C, S, P, Se, I, B, Si.
1 " fluid: Br.
5 " gaseous: O, H, N, Cl, (Cy).

7. They form four families or groups, founded on their resemblance to each other.

1st group, Organogens, animal and plant producers: O, H, N, C.
2d " Pyrogens, fire producers: S, P, Se.
3d " Halogens, salt producers: Cl, I, Br, F, (Cy).
4th " Hyalogens, glass producers: B, Si.

ACIDS.

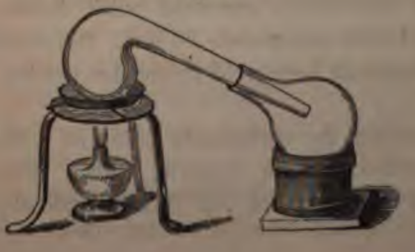
FIRST GROUP: OXYGEN ACIDS, OR COMBINATIONS OF THE METALLOIDS WITH OXYGEN.

NITROGEN AND OXYGEN.

1.) *Nitric acid*, or aquafortis ($H O, N O_5$).

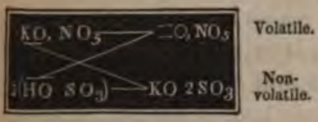
159. *Experiment.* — Introduce into a small retort half an ounce of powdered saltpetre and half an ounce of common sulphuric acid, and let the retort stand erect for some time, in order that as much as possible of the sulphuric acid remaining in the neck may flow down into the retort. Then imbed the latter

Fig. 87.



in sand contained in an iron vessel, adapt to the beak of it a receiver, wrap round the joint some strips of moistened blotting-paper, and heat gently. In a short time a yellowish fuming fluid passes over into the receiver, which is placed in a vessel filled with water, and must frequently be sprinkled with cold water; this fluid is heavier than water, and is called *nitric acid.*

Saltpetre is a salt, consisting of nitric acid and a base. The base is called oxide of potassium, or more briefly potassa, and has for its symbol K O. Sulphuric acid is a stronger acid than nitric acid; that is, it has a greater affinity than the latter for potassa; it therefore expels the nitric acid, which, by the application of heat, is converted into vapor, but is condensed again in the receiver as a fluid. A quarter of an ounce of sulphuric acid would indeed have been sufficient to expel all the nitric acid, but the process is conducted much more easily when double the quantity is employed. This explains why the saline residuum left in the retort has still a very acid taste; it is called *bi*sulphate of potassa. If only one half of the sulphuric acid had been employed, *neutral* sulphate of potassa would have remained behind.



Nitric acid has the same constituents as common air, but in different proportions. The air contains for every four measures of nitrogen one measure of oxygen; nitric acid, on the contrary, contains ten times more of the latter element; consequently, for every four measures of nitrogen, ten measures of oxygen; or, what is the same thing, for every two measures of N (1 atom), five measures of O (5 atoms). These two gases are only mechanically mixed together in the air, but in the nitric acid, on the contrary, they are chemically combined. This is a striking example how wonderfully the properties of bodies change, when they chemically combine with each other. When mechanically mixed together, the constituents of nitric acid form a life-sustaining gas, while, when chemically combined, they form one of the most corrosive fluids.

It might, perhaps, be supposed that nitric acid could be formed more directly and simply from the air; but this cannot be done, because the inert nitrogen will not voluntarily combine with oxygen; this combination can only be effected by a circuitous method, which will be described hereafter.

The strongest nitric acid contains in every pound two and a quarter ounces of water, or in each atom of acid one atom of water, without which latter it cannot exist; if this is withdrawn from it, it is resolved into oxygen and a lower oxygen-compound of nitrogen. Many other bodies, especially organic bodies, behave in a similar manner. This water has been called *water of constitution*, denoting thereby that it is indispensably necessary to the constitution—to the existence—of the bodies referred to. The water of crystallization is necessary only to the continuance of the *form* and *shape* of the crystals. The crude nitric acid of commerce, which is commonly prepared in large iron cylinders, contains, perhaps, from 10 to 12 ounces of water in the pound; consequently it is three or four times weaker than the above.

160. *Experiments with Nitric Acid.*

Experiment a.— A drop of nitric acid is sufficient to acidify several spoonfuls of water, and even at a greater dilution it will redden blue litmus-paper; nitric acid is *accordingly* distinctly characterized as an acid.

Experiment b. — The well-known volatile alkali, more correctly called ammonia, may serve as the antithesis to the acids. It has an alkaline taste, has no action on blue test-paper, but turns red test-paper blue; it has the character of a *base*. Its exceedingly pungent odor is also characteristic.

Experiment c. — Add carefully, and by drops, some nitric acid to half an ounce of ammonia, until the color of red or blue test-paper remains unchanged by it. When this point is attained, you will no longer perceive either the acid or the alkaline taste or smell. The taste has become *saline*, the smell has vanished. This process, as already mentioned, is called *neutralization*. Upon evaporating the solution a white *salt* remains behind, nitrate of ammonia. By appropriate means, the nitric acid, as well as the ammonia, may be again liberated from this salt.

It is characteristic of all acids, that *they combine with bases, forming entirely new bodies, called salts*, and thus lose their acid properties.

Experiment d. — If lead be heated for a long time in the air it abstracts oxygen from it, and becomes converted into a reddish-yellow powder, called oxide of lead, or, popularly, litharge. Take up a small portion of this litharge on the point of a knife, put it into a test-tube, and add some nitric acid. The greater part will be dissolved by gentle heating. Filter the solution while warm, and put it in a cold place; a salt will be deposited from it in white brilliant crystals of nitrate of oxide of lead. This shows that oxide of lead is also a base, as it combines with acids forming salts. This salt is soluble in pure water.

Nitric acid dissolves most of the metallic oxides, and forms with them salts, all of which are soluble in

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smell. This vapor is called nitro
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verted it into an oxide. Part of
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In this case nitric acid exerts,
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with all other metals which are s
as, for example, with silver, mercu

ple, wool, feathers, wood, indigo, &c., are oxidized and decomposed by heating with nitric acid. This sort of decomposition may be regarded as combustion in the moist way. If organic substances are allowed to remain for a short time only in contact with this acid, they will assume a yellow color, owing to the evolution of nitrous acid. In this manner wood may be stained, and silk may be died yellow; the hands and clothes are also stained yellow by nitric acid. Cotton experiences a most remarkable change if soaked for a short time in the *strongest* nitric acid; it will then detonate and explode, like gunpowder, only far more violently. (See *Gun-cotton*, in the second part of this work, under the head of *Vegetable Fibre*.) Strong nitric acid is partially decomposed, and colored yellow, by the rays of the sun.

Nitric acid, as the preceding experiments show, is *very easily decomposed*, and with the liberation of oxygen, which, in the nascent state, has the greatest desire to combine again with other bodies. Nitric acid is, owing to this property, one of the most important *means of oxidation*.

Experiment h. — The nitric acid salts, also, are easily decomposed. Having powdered some of the nitrate of lead, obtained in experiment *d* or *e*, throw it upon a red-hot coal; decomposition will ensue, with the emission of sparks, and beads of metallic lead will remain behind. The nitric acid will hereby be completely resolved into nitrogen and oxygen; the latter, as well as the oxygen of the oxide of lead, combines with the coal, forming carbonic acid, which, together with the nitrogen that has become gaseous, quickly escapes and occasions the emission of sparks. This sudden evolution of gases from a solid body is called *detonation*.

2.) *Nitrous Acid* ($N\,O_3$).

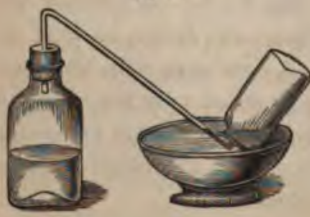
161. This acid is always produced as a disagreeable secondary product from nitric acid, when this, as in the previous experiment, is employed for dissolving or oxidizing metals or other substances. At the common temperature it forms *reddish-yellow suffocating fumes*, which at a very low temperature may be condensed into a blue liquid. As the inhalation of these vapors is injurious to the lungs, experiments performed with this acid should always be done where there is a free circulation of air.

Fuming Nitric Acid. — Nitric acid will dissolve large quantities of nitrous acid fumes, and is thereby converted into a reddish-yellow liquid, which in open vessels gives off the same colored fumes. It is then called *fuming nitric acid* ($N\,O_3 + N\,O_5$). On dilution with water it becomes, first green, then blue, and finally colorless, while the nitrous acid escapes.

3.) *Nitric Oxide* ($N\,O_2$).

162. *Experiment.* — Pour over a cent, placed in a wide-mouthed bottle, a little water, and then add by degrees some nitric acid, until a brisk effervescence ensues. This effervescence is caused by the evolution of a gas, which must be collected in a jar of white glass over the pneumatic trough. It is called *nitric oxide*, and consists of two measures (1 at.) of nitrogen and two measures (2 at.) of oxygen. Close the mouth of the jar under water; it seems to be empty, for the nitric oxide is colorless; but if the jar be opened, and air be carefully blown in, then the jar becomes

Fig. 88.



lled from above with yellowish-red vapors. The ni-ric oxide takes thereby from the air one atom of oxygen, and is converted into nitrous acid, and NO_2 becomes NO_3. On account of this property, it has an important application in the preparation of common sulphuric acid (§ 172). It is here formed from nitric acid, because the copper withdraws from it three atoms of oxygen, and becomes an oxide, which combines with undecomposed nitric acid, forming nitrate of the oxide of copper. This salt is obtained in blue crystals by evaporating the solution of the cent.

163. 4.) *Nitrous Oxide* (NO) is a combination of two measures (1 at.) of nitrogen with one measure (1 at.) of oxygen; it is a colorless gas, which, when inhaled, has an intoxicating effect, and is therefore called also exhilarating gas. This gas may be regarded as atmospheric air, containing double its usual amount of oxygen.

By the following table it will be seen that both the volumes and the weights of the constituents of the four compounds just treated of are in regular proportion: —

In *Weight.*				In *Volume.*			
oz.		oz.					
175	N. with	500	O,	or 2 vols. (1 at.) N.	with	5 vols. (at.) O,	to NO_5.
175	— "	300	—	" 2 " (1 at.) —	"	3 " "	— " NO_3.
175	— "	200	—	" 2 " (1 at.) —	"	2 " "	— " NO_2.
175	— "	100	—	" 2 " (1 at.) —	"	1 " "	— " NO.

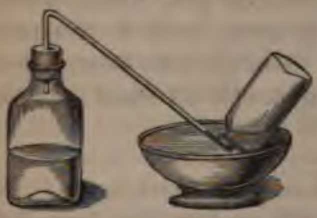
By one measure or atom of oxygen (O) is here meant 100 ounces, grains, &c., in weight. On the other hand, by two measures or one atom of nitrogen (N) is meant a quantity in weight of 175 ounces, grains, &c.

CARBON AND OXYGEN.

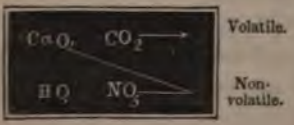
1.) *Carbonic Acid*, or *fixed air* (CO_2)

164. It has already been shown, when treating of carbon, that coal and all our combustible substances form, during brisk combustion, carbonic acid (§ 115), and that this gas may be detected by lime-water, which is thereby rendered turbid, owing to the formation of an insoluble salt, carbonate of lime. Chalk, limestone, and marble are also carbonates of lime, and from them carbonic acid may be prepared in large quantities.

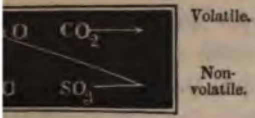
Fig. 89.



Experiment. — Pour into an eight-ounce flask half an ounce of nitric acid and half an ounce of water, and then add some pieces of chalk or limestone. Adapt to the flask a bent glass tube, and conduct the gas, which escapes with effervescence, into a jar placed over the pneumatic trough, and collect it, as was directed under oxygen. The stronger nitric acid expels the feebler carbonic acid, while it combines with the base-lime (CaO). The nitrate of lime formed (CaO, NO_5) is a soluble salt; therefore there remains in the flask a clear liquid, from which, by evaporation, the nitric acid salt may be obtained in a solid form.

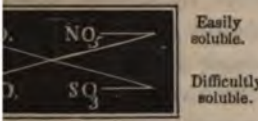


Experiment. — Repeat the experiment, but instead of nitric acid take half an ounce of sulphuric acid (SO_3), *carefully* diluted with two ounces of water (§ 84); you *will obtain* carbonic acid and sulphate of lime. The d in this case does not become clear, since the sulphate of lime $(Ca\,O,\ S\,O_3)$ is a salt difficult to dissolve; it is the same substance with that commonly called gypsum, or plaster of Paris.



ng finished the experiment, collect and dry the um, and preserve it for future experiments. The two experiments are obvious examples of simple ive affinity.

periment. — Add some sulphuric acid to the nicid solution of the first experiment; the clear liquid will become thick and turbid, gypsum being likewise formed, because sulphuric acid, which is stronger than the nitric acid, expels the , and combines with the lime.



5. *Experiments with Carbonic Acid.*

periment a. — If moistened blue test-paper is exd to carbonic acid it is reddened, but on being left e air for some time the blue color is restored; car acid is a *volatile acid.*

90.

Experiment b. — A burning taper is extinguished when held in carbonic acid, and it is fatal to men and animals if they inhale it. Carbonic acid gas can *neither support combustion nor life.*

Experiment c. — Invert a jar filled with carbonic acid over one containing only atmospheric air; if after some moments you introduce into each of these jars a burning taper, that in the upper vessel will continue to burn, while that in the lower one will be ex-

Experiment d.— Repeat the e
jars, filling, instead of the upper c
carbonic acid. If, after some hou
to both of the jars, and shake the
both of them a precipitate of ca
proof that the carbonic acid has
the upper jar. Both gases have
gether, or the carbonic acid, thoug
ed, and the common air, though
itself towards the bottom. This
the different kinds of gases toget
of gases. This diffusion of gase
maintains a constant equality an
stituents of the atmosphere, is of
the economy of nature, and acco
the constitution of the air is eve
form, although in one place free
from it, and in another place car
to it.

Experiment e.— Fill a flask con

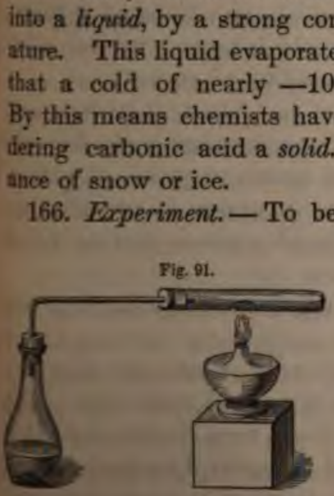
from the earth in many places, for instance, at Selters and Bilin, and they are used for their medicinal qualities, under the name of *carbonated waters*. They are now also prepared artificially. From this it appears that carbonic acid is innocent when taken as a drink, but is injurious when inhaled. The foaming of bottled beer and champagne is owing to carbonic acid, formed during the fermentation of these liquors, and kept confined in the bottles by corking them.

Experiment f.— Throw a piece of chalk into vinegar; vinegar is one of the weakest acids, yet it is able to expel carbonic acid; this escapes with effervescence. Carbonic acid is a *very feeble acid*, because it has a very great inclination to become gaseous.

Formerly carbonic acid was only known in its gaseous state; but in recent times it has been converted into a *liquid*, by a strong compressure at a low temperature. This liquid evaporates with such great rapidity, that a cold of nearly —100° C. is produced (§ 40). By this means chemists have lately succeeded in rendering carbonic acid a *solid*. It then has the appearance of snow or ice.

166. *Experiment.*— To be perfectly convinced that carbon is contained in the colorless carbonic acid gas, take a test-tube, break the bottom of it, and adapt to it, by means of a perforated cork, a glass tube, and connect it with a flask in which carbonic acid is evolved (§ 164). Introduce into the test-tube a piece of potassium of the size of a pea, previously dried between blotting-

Fig. 91.



paper, and heat the place where it lies with a lamp. Potassium is a metal very similar to sodium, and has, like that, an extraordinary affinity for oxygen; at the degree of heat produced by the lamp, it is enabled to withdraw the oxygen from the carbonic acid which passes over it. This takes place, and oxide of potassium, or, more simply, potassa ($K O$), is formed, one of the strongest bases, which immediately combines with a portion of the acid present, forming carbonate of potassa. This is colored black by the separation of carbon. If you put the test-tube, containing the black saline mass, into a wide-mouthed flask, in which there is some water, the carbonate of potassa will dissolve, but the carbon will float mechanically in the solution, and may be collected on a filter. The liquid has a basic reaction, since the feeble carbonic acid is not able fully to neutralize the alkaline properties of so strong a base as potassa. The presence of carbonic acid is proved by the effervescence produced on the addition of an acid.

Carbonic acid consists of one atom of carbon and two atoms of oxygen, and has consequently the formula $C O_2$. By weight, then, 75 ounces or grains of carbon are united with 200 ounces or grains of oxygen; accordingly, one atom of carbon is equal in weight to 75 ounces, grains, &c. of carbon.

167. Carbonic acid is everywhere unceasingly generated, and especially, —

a.) In those regions of the earth where volcanoes are active, or probably were active in a former age. It is generated at the Grotto del Cane, near Naples, — at Pyrmont, in Westphalia, — and in the neighbourhood of the Lake of Laache, &c.; and it oozes in a constant current from various *crevices* in different parts of the *earth*.

b.) In all ordinary *combustions*, as has already been *mentioned* several times.

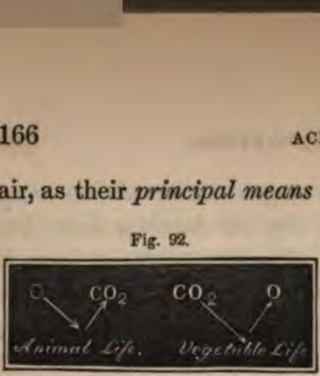
c.) In the *respiration* of men and animals, as may easily be proved by blowing the air coming from the lungs through a glass tube into lime-water; carbonate of lime is formed, which renders the clear liquid turbid. We inhale oxygen; this combines in our bodies with carbon, and is again exhaled as carbonic acid; therefore, in those crowded apartments where many people congregate, or where many lights are burning, some arrangement should be made by which the vitiated air, that is, air rich in carbonic acid, may be conducted off, and be replaced by fresh air, that is, air rich in oxygen. This is accomplished by means of artificial currents of air, or ventilation.

d.) In the *fermentation* which occurs in the making of wine, beer, and brandy. In this process the sugar is resolved into alcohol and carbonic acid; the former remains in the liquor, and imparts to it an intoxicating power, while the carbonic acid escapes in the air.

e.) In the decay and *putrefaction* of all animal and vegetable substances. Carbon is contained in all organic bodies; during decay it is converted gradually by the oxygen of the air into carbonic acid; hence, wherever plants and animals exist, whether upon the earth, in the sea, or in the air, carbonic acid must be formed.

All the carbonic acid thus formed is received into the air. If it should continue there, however, the air would become gradually deteriorated, more especially as, in all the processes of breathing, combustion, and decay, free oxygen or vital air is taken from it. But this is not the case. The oxygen does not decrease. The carbonic acid does not increase. An unfathomable wisdom has appointed the vegetable kingdom as the protector of animal life, and, with wonderful simplicity, has *provided that plants* should absorb from the air, as their *principal means of support*, the carbonic acid exhaled, as useless, by men and animals, and should yield oxygen to them in return. Plants inhale carbonic acid, and (during the day) exhale oxygen.

Fig. 92.



2. *Carbonic Oxide* ($C\,O$) has already been treated of. (§ 110.)

SULPHUR AND OXYGEN.

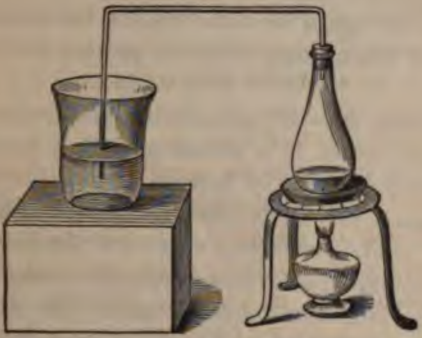
1.) *Sulphuric Acid* ($S\,O_3$).

168. What iron is to the machinist, sulphuric acid is to the chemist. As the former makes out of iron, not only machinery of all sorts, but also instruments by which he can work up every other material, so sulphuric acid has also for us a double interest. It not only forms with the bases very important salts, but we employ it also as the most useful chemical means for producing numerous other chemical substances and changes, as has already been taught in the preparation of hydrogen, phosphorus, chlorine, nitric acid, carbonic acid, &c. Since it has come into general use for the cleaning of metallic implements, for the kindling of matches, and for making blacking, &c., it is well known as a sharp, corrosive fluid. It stands, as it were, the Hercules among the acids, and by it we are able to overpower all others, and expel them from their combinations. It occurs in commerce as a liquid only. There are two sorts; 1) an oily fuming liquid (Nordhausen sulphuric acid, or oil of vitriol); and 2) another somewhat thinner, and not fuming, acid (common sulphuric acid). But it may be obtained in a solid and dry state in the following manner.

169. *Anhydrous Sulphuric Acid.*

Experiment. — Pour into a small flask, placed in a sand-bath over a tripod (see Fig. 93), half an ounce of Nordhausen sulphuric acid, and heat it gently till it boils moderately. Conduct the vapor through a sufficiently wide glass tube into an empty flask, which is placed in a vessel filled with cold water. In summer time the water may easily be made colder by adding to it a teaspoonful of powdered saltpetre. If the vapor be suffered to escape into the air, it appears in thick white fumes, having a pungent acid smell; but if conducted into the flask, it is condensed into a glistening white, solid mass. This is *anhydrous sulphuric acid.* The distillation stops as soon as the boiling ceases, and the glass tube becomes so hot as to burn the hand. What remains in the flask no longer fumes; it has become common sulphuric acid. To cause this to boil, you must apply a ten times stronger heat than before, for it does not begin to boil till above 300° C., while the anhydrous acid boils even at a little above 30° C. This is the reason why the boiling ceases when the latter has escaped.

Fig. 93.



Experiments with Anhydrous Sulphuric Acid.

Experiment a. — Take out some of the acid by means of a glass rod, and introduce it into a dry test-tube; it will fume violently, and after a time become fluid; *that is, it attracts water* from the air, and is thereby converted into Nordhausen sulphuric acid. On longer standing it absorbs still more water, and ceases to fume; it thus becomes common sulphuric acid. By evaporation this water cannot again be removed, for the sulphuric acid will deliver this up only when we present to it a base in exchange.

Experiment b. — If anhydrous sulphuric acid be thrown into water, it is dissolved with a hissing noise, and a *violent evolution of heat.*

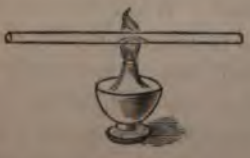
Experiment c. — It is likewise dissolved in common sulphuric acid, converting this into the fuming acid. Fuming sulphuric acid is accordingly a solution of anhydrous in common sulphuric acid. Its constituents are, by weight, 200 of sulphur (1 atom) and 300 of oxygen (3 atoms). Hence its symbol = $S\,O_3$.

170. *Fuming Sulphuric Acid.*

This is obtained by the distillation of green vitriol, which, as is known, consists of sulphuric acid and protoxide of iron. (§ 89.)

Experiment. — Put a crystal of green vitriol into a glass tube, and heat it; aqueous vapor escapes, and the green crystal becomes white (anhydrous). On further heating the white color passes into reddish-brown, and a little sulphurous acid is evolved; a portion of the sulphuric acid gives up one atom of oxygen to the protoxide of iron, which

Fig. 94.



it thus converts into a sesquioxide, while the other portion combines with the oxide of iron. If this basic sulphate of sesquioxide of iron be strongly and continuously heated, then the sesquioxide of iron releases the sulphuric acid; and this escapes, and becomes anhydrous, because it no longer finds any water present. In preparing it on a large scale earthen retorts are used, and the fumes are conducted into common sulphuric acid, which is thereby converted into fuming acid. As this is a thick, flowing liquid, like oil, and is prepared from green vitriol, it has received the name of oil of vitriol; it is also called Nordhausen sulphuric acid, because this city supplied Germany with it for centuries. Oil of vitriol has the specific gravity of 1.9, and contains for every pound about 2 or 2½ ounces of water.

If oil of vitriol be exposed to the air, the anhydrous acid in it evaporates and unites with the vapor contained in the air; accordingly, common sulphuric acid is formed, which, being ten times less volatile, condenses in the cold air, forming white vapors, just as steam does. Consequently, the fumes of oil of vitriol consist of the vapor of common sulphuric acid.

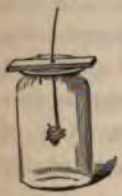
As long as the process of manufacturing sulphuric acid from green vitriol alone was known, it was a very expensive article. A hundred-weight is now obtained for the same sum that was formerly paid for two pounds.

171. *Common Sulphuric Acid* (HO, SO_3).

Charcoal and phosphorus on burning take up the greatest quantity of oxygen with which they can combine, and we obtain carbonic and phosphoric acids. If sulphur did the same, nothing would be easier than to convert it into sulphuric acid. But sulphur, on burning, forms sulphurous acid (SO_2), that is, 200 in weight of sulphur (1 atom) combines with 200 in weight of oxygen (2 atoms). To convert this into sulphuric acid, it must be compelled to take up another 100 in weight of oxygen (1 atom). This is done by a body which is very rich in oxygen, and which likewise readily parts with it, namely, by nitric acid.

Experiment. — Fasten some bits of sulphur to an iron wire, inflame and hold them in a capacious bottle containing a little water, until the blue sulphurous flame is extinguished; the bottle becomes filled with a white smoke, which is recognized by its odor as sulphurous acid. (§ 64.) If you now introduce a shaving moistened with nitric acid into the vessel, reddish-yellow fumes will immediately form around the wood, gradually filling the whole bottle. These fumes are nitrous acid, and their evolution indicates that the sulphurous acid has withdrawn oxygen from the nitric acid, and has been oxidized and converted into sulphuric acid. After some time the flask becomes clear again, because the vapor of the sulphuric acid formed sinks to the bottom, and dissolves in the water, and we can now once more burn sulphur in the bottle. If we repeat this operation several times, we can soon prepare a few ounces of diluted sulphuric acid.

Fig. 95.

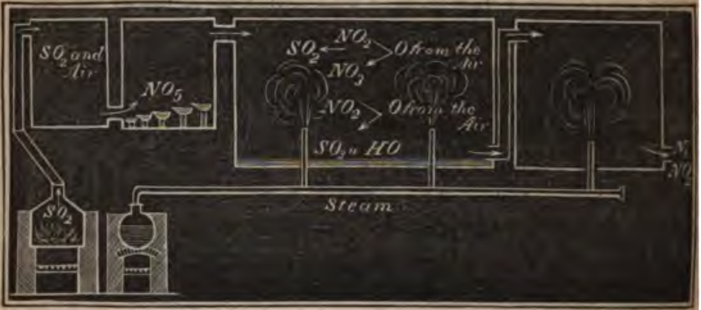


Experiment. — Add some drops of a solution of a *salt of barium* (chloride of barium) to a portion of the acid liquid just obtained; a strong white precipitate is formed, which disappears neither by boiling, nor by the addition of water, nor by nitric acid. This precipitate is *sulphate of baryta*, a salt quite insoluble in water and acids. Add one drop of the diluted acid to a wineglass-*full of* water, and add to this a solution of barium; even at this great dilution, a perceptible cloudiness will be produced. A solution of chloride of barium, or of nitrate of baryta, are the most certain reagents for detecting sulphuric acid and sulphates.

172. *The manufacture of common sulphuric acid on a large scale* is conducted on the same principle as in the last experiment but one. The sulphur is burnt in an oven, from which a pipe leads into large leaden chambers. Vessels containing *nitric acid* are placed in one of the chambers, and some *water* is poured upon the floor. The *sulphurous acid* abstracts one atom of oxygen after another from the nitric acid, till this is converted into nitric oxide. The *nitric oxide* formed now acts in a very peculiar manner. It has been stated (§ 162) that this gas ($N\,O_2$), on coming in contact with the air, immediately abstracts from it one atom of oxygen, forming yellowish-red fumes of nitrous acid ($N\,O_3$); the same thing takes place in the leaden chambers, since *air* also flows into the chambers at the same time with the sulphurous acid. The nitrous acid willingly gives up again this one atom of oxygen to bodies which have a desire for it. Such a body is sulphurous acid. Although it is too inert to take the oxygen directly from the air, it nevertheless receives the oxygen very willingly when it is presented to it by the nitrous acid. Thus the latter becomes again converted into nitric oxide, but the former into sulphuric acid. The nitric oxide again takes oxygen from the air, and gives it up again to the sulphurous acid, and continues to perform this service as long as any oxygen is present. Finally, it is allowed to escape, together with the remaining nitrogen of the air. But it is essential for the success of this process, that *vapor* be also present; therefore steam is continually conducted into the chambers from a steam-boiler.

This steam, together with the sulphuric acid formed, condenses on the cold walls, and collects on the floors of the chambers as an acid liquid. The annexed figure tends to elucidate this process.

Fig. 96.



By means of this remarkable property of nitric oxide, it has become possible, with an ounce of nitric acid, to obtain from 10 ounces of sulphur 30 ounces of concentrated common sulphuric acid. If the three atoms of oxygen released from the nitric acid were all the oxygen that operated, we should require more than 20 ounces of nitric acid to prepare 30 ounces of sulphuric acid. There are now some laboratories for the manufacture of sulphuric acid, of such colossal size, that they are able to deliver daily several hundred quintals of prepared acid. The diluted acid formed in the leaden chambers requires still to be evaporated down nearly one half, in order to convert it into common *concentrated sulphuric acid.* This evaporation is commenced in leaden vessels, and finished in glass or platinum retorts. The water, being more volatile, escapes, and carries off with it only a small portion of the acid.

hen the specific gravity of the latter becomes 1.84,
at is, when 1840 grains of the acid can be put into a
essel capable of containing just 1000 grains of water,
e evaporation is stopped, and the acid is transferred
large glass bottles, or carboys. One pound of com-
on sulphuric acid contains three ounces of water, and
nsists of one atom of acid and one atom of water; but
is atom of water is retained so firmly, that it cannot
expelled by any heat. This acid is therefore called,
so, *hydrated sulphuric acid*, $= HO, SO_3$.

173. *Experiments with Sulphuric Acid.*

Experiment a. — Let some sulphuric acid remain in
n open flask exposed to the air; it will increase every
ay in weight, *for it very eagerly attracts water from the
r.* After standing for some months in a damp place,
will become two or three times heavier than before.
his explains why the match-flasks formerly in use so
eadily became saturated with water. Some sub-
tances impregnated with water, especially gases, are
ried by means of sulphuric acid.

Experiment b. — A piece of wood introduced into
ulphuric acid becomes black, and is reduced to coal, as
f it had been exposed to the flame of a lamp. The
ulphuric acid seizes upon its hydrogen and oxygen,
hich combine to form water, and the carbon is left
ehind. Wood may be charred in this way, in order to
rotect it from decay in moist situations. In the refin-
g of burning-oil, the slime of the oil is charred by sul-
huric acid. *Sulphuric acid chars and destroys most
getable and animal substances.*

Experiment c. — Pour a drop of oil of vitriol upon
per; decomposition takes place slowly; but it will
ke place instantaneously, if some drops of water are
ded, because *water and sulphuric acid unite together*

with the evolution of strong heat. For this reason, when sulphuric acid comes in contact with the skin, it should first be wiped off with dry paper or cloth, and then be immediately washed with a great quantity of water. If 50 measures of sulphuric acid are mixed with 50 measures of water, we do not obtain 100 measures, but only 97 measures, of liquid; consequently a contraction or condensation has occurred, which condensation is always attended with the liberation of heat.

Experiment d. — Pulverize a small quantity of *indigo*, and form a thin paste of it with *fuming sulphuric acid*. After a few days add to it some water, and you obtain a deep blue liquid, — solution of indigo. With this solution wool may be dyed of a fine blue color (Saxon-blue). Common sulphuric acid dissolves indigo only imperfectly. Indigo, although a vegetable substance, is not carbonized by sulphuric acid, thus forming an exception to the general rule.

Experiment e. — If, during the winter season, you place one vessel containing fuming sulphuric acid, and another containing the common acid, in a cold place, the stronger oil of vitriol will freeze at 0° C., but the weaker common sulphuric acid will not freeze until the temperature falls to —34° C.

Experiment f. — Dissolve half an ounce of the soda of the shops in warm water, and neutralize with dilute sulphuric acid; evaporate until a film forms over the surface, when, on cooling, prismatic crystals will be deposited; they possess a bitter saline taste, and are *easily soluble* in water. The common soda of the shops is carbonate of soda ($Na\,O, C\,O_2$); the carbonic acid is displaced by the stronger sulphuric acid, and escapes with effervescence, but sulphate of soda (Glauber salts) *remains* behind in the liquid. Almost all spring-water contains small quantities of soluble sulphates; the insoluble or almost insoluble sulphates are often accumulated in enormous masses in nature, forming whole mountains, as, for instance, gypsum.

Experiment g. — Mix to a thin paste half an ounce of litharge with water, and add gradually a quarter of an ounce of common sulphuric acid; after a while a white insoluble body is formed. The acid unites with the oxide, forming sulphate of the oxide of lead; this is *an insoluble salt.*

Experiment h. — To half an ounce of copper scales, such as fall off in copper founderies, add two ounces of water, and then gradually two thirds of an ounce of sulphuric acid, and put it in a warm place; you obtain a blue solution, from which afterwards blue oblique, rhomboidal crystals will be deposited. The edges of these crystals are usually obtuse, giving to the slender sides a roof-like appearance. Copper scales are oxide of copper; and they combine with the acid, forming sulphate of oxide of copper (blue vitriol), a *soluble* salt. By the designation *vitriol* is always to be understood a sulphate of a metallic oxide. Copper or iron vessels are cleaned more rapidly and made brighter by water to which some sulphuric acid has been added, than by simple water alone, because the oxide, which tarnished the vessels, is dissolved by the acid.

Experiment i. — Put a small iron nail into a test-tube, and drench it with 20 drops of common sulphuric acid; it is not acted upon. But if you add a little water, about four or five times more than the acid, a brisk effervescence will ensue, and the iron will be dissolved. The strong acid may be heated to boiling in iron vessels without acting upon them, which is by no means the case with the diluted acid. It has been stated (§ 89) that, in this experiment, hydrogen escapes, and sulphate of iron remains in solution. The iron becomes protoxide of iron, not through the oxygen of the acid, but through that of the water. Zinc and tin comport themselves in the same manner. Consequently, *diluted acid* must be employed for dissolving such metals. But there are also metals which dissolve only in stronger acid, for instance, copper, silver, &c.; this will be treated of more fully under sulphurous acid.

Experiment k. — If a meadow or field be irrigated with one pound of sulphuric acid, diluted with 1000 pounds of water, the soil will be rendered more fertile and productive. The reason is, that the sulphuric acid decomposes and renders soluble several kinds of earth; whereby soluble sulphates are formed, which are absorbed by the plants, and accelerate their growth. Sulphuric acid, if only 100 times diluted, has the contrary effect, and may serve for destroying grass and weeds in alleys, &c.

2.) *Sulphurous Acid* ($S\,O_2$).

174. This suffocating gas is formed, not only by the combustion of sulphur, but may also be prepared from sulphuric acid, by depriving this acid of one atom of oxygen.

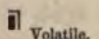
Experiment. — Put into a flask (see Fig. 93) half an ounce of copper filings, and two ounces of common sulphuric acid, and conduct the gas ($S\,O_2$), as it escapes, into a four-ounce bottle filled with water (for the precaution to be taken, see § 92); the gas will be absorbed by the water in great quantities, and will impart to it an acid taste and a suffocating odor, like that of burning sulphur. One measure of water dissolves about forty measures of sulphurous acid. When the gas ceases to be absorbed by the water, substitute a flask filled with a solution of carbonate of soda; this likewise absorbs the gas, and forms with it sulphite of soda, while the carbonic acid of the carbonate of soda escapes. After sufficient evaporation, the salt formed will shoot out into white crystals, now known in commerce by the name of antichlorine; it is able to bind the chlorine that may happen to remain in the material during the bleaching, and to render it harmless. Sulphite of soda has not the odor of sulphurous acid, unless when drenched with diluted sulphuric acid, which combines with the soda, and expels the feebler sulphurous acid.

Experiment. — Infuse logwood shavings in warm water, and pour on the dark liquid thus obtained some sulphurous acid water; a decolorization of the liquid will immediately take place. Sulphurous acid *bleaches vegetable colors.* Straw, wool, silk, and catgut — indeed animal substances especially — are quite generally bleached with sulphurous acid. The most simple method is to moisten them with water, and suspend them in a chamber or in a box, on the floor of which is placed a vessel containing burning sulphur. The bleaching power of this acid is beautifully exemplified by holding a rose or a peony over a burning stick of sulphur. If some drops of strong sulphuric acid be now added to the bleached infusion of logwood, the previous dark red color *will again be restored;* consequently the coloring matter has not been completely destroyed by the sulphurous acid, as it would have been by chlorine; but it has only combined with the acid, forming a colorless combination, which may be broken up again by a stronger acid.

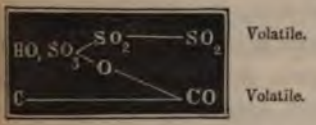
Experiment. — If a lighted taper is held over burning sulphur, or introduced into a vessel of sulphurous acid gas, it *will be extinguished,* as it was by nitrogen or by pels the atmospheric air present in it, is thereby deprived of the free oxyg guished.

175. It now remains to inquire, wha the copper and the sulphuric acid, fro phurous acid was prepared.

Experiment. — When the residue in come cold, add water to it, and heat it until the whole saline mass is dissolve is dark and turbid, because fine parti tained in almost every metal, are floa but after filtering, it is of a beautifu transparent. If allowed to cool slowl sulphate of the oxide of copper (blue siderable size, are formed; it is identi obtained by the solution of the cop phuric ac by which oxidized the sulp which g



more economical previously to convert the copper into an oxide by heating it in the air, and then dissolving it in sulphuric acid. Silver and mercury comport themselves also like copper. When they are to be dissolved in sulphuric acid, *concentrated* acid must be used.



When larger quantities of sulphurous acid are required, it is usually prepared by heating sulphuric acid with charcoal. The coal likewise abstracts one atom of oxygen from the sulphuric acid, and becomes converted into carbonic oxide, which escapes in company with the sulphurous acid.

The following proportions, in weight, of sulphur and oxygen, always exist in the two combinations just considered: —

200 oz. of sulphur and 300 oz. of oxygen, or 1 at. S and 3 at. O, form $S\,O_3$.
200 " " " 200 " " " 1 " S and 2 " O, " $S\,O_2$.

Sulphur forms with oxygen several other acid combinations, as hyposulphuric acid, trithionic acid, hyposulphurous acid, tetrathionic and pentathionic acids; but these, as less important, will not be treated of here.

PHOSPHORUS AND OXYGEN.

1.) *Phosphoric Acid* ($P\,O_5$).

176. When phosphorus burns with a flame in oxygen, or in the air, a white acid vapor, called *phosphoric acid* (§ 65), is formed; 400 grains of phosphorus are thereby always combined with 500 grains of oxygen, or 1 atom of phosphorus with 5 atoms of oxygen; this

boiling phosphorus a long time with
preparation of it by combustion, th
oxygen ; on boiling with nitric acid,
plies it. We find phosphoric acid,
existing in many substances, especi
of the Mammalia and birds, from
prepared.

Experiment. — Weigh a *bone*, put
and let it remain there for some hou
black and then again white. Now t
and again weigh it; it has lost abo
weight. That which was lost in bu
which was first charred by the heat a
that is, converted into gas, which
maining non-volatile parts are call
consist principally of phosphate of l
to a fine powder. Put two thirds of
a flask, and add to it half an ounc
and four ounces of water ; let it stan
a warm place, occasionally shaking

is the case; if gypsum is heated to redness with phosphoric acid, the sulphuric acid will be driven off, so extraordinary are the changes which affinities experience at different temperatures. At a great heat, the least volatile acids are always the strongest; among these belongs phosphoric acid, since it does not volatilize until it attains a white heat. If this phosphoric acid is evaporated, we obtain it (still containing some lime), first as a sirupy liquid, and finally as a vitreous solid mass.

To detect phosphoric acid, add to a solution of it some drops of nitrate of silver and ammonia; a yellow precipitate is produced (phosphate of the oxide of silver). But if the acid had been previously ignited, the precipitate would have been white; consequently, the properties of phosphorus are partially changed by strong ignition.

The body of an adult man contains about
from 9 to 12 pounds of bones, containing
" 6 " 8 pounds of bone ashes, containing
" 5 " 7 pounds of phosphate of lime, containing
" 2¼ " 3 pounds of phosphoric acid, containing
" 1 " 1¾ pounds of phosphorus.

Phosphates are also contained in the blood, flesh, and other portions of the body. Whence does it obtain this phosphorus? Answer; from the meat and vegetables which it consumes. The phosphate salts occur in bread, in all kinds of grain, in leguminous and many other plants, particularly in their seeds. But how do the plants obtain these salts? By means of the soil. If arable land contained no such salts, no seeds could be produced. If we increase their quantity by mixing bone-ashes with the soil, we place the latter in a situation to produce a larger quantity of grain; consequently, bones furnish us with a powerful manure. That the gelatine contained in them contributes also to the growth of plants, will be treated of hereafter.

2.) *Phosphorous Acid* ($P\,O_3$).

177. This acid, which contains for one atom of phosphorus only three atoms of oxygen, is formed principally when phosphorus is slowly burnt, that is, when without being heated it takes up oxygen from the air, as was shown in § 140.

3.) A combination of equal atoms of phosphorus and oxygen is called *hypophosphorous acid.*

4.) *Oxide of Phosphorus* ($P_2\,O$). The red substance formed during the imperfect combustion of phosphorus (§§ 142, 143) contains even less oxygen than hypophosphorous acid, and is called *oxide of phosphorus.*

In phosphoric acid ($P\,O_5$), 400 ounces of phosphorus are always combined with 500 ounces of oxygen, or 1 atom P with 5 atoms O; in phosphorous acid ($P\,O_3$), 400 ounces of phosphorus are always combined with 300 ounces of oxygen, or 1 atom P with 3 atoms O.

CHLORINE AND OXYGEN.

178. *Chlorine* has but a feeble affinity for oxygen, and may be combined with it only in an indirect way, and with the assistance of strong bases, which immediately unite with the acids produced, forming salts.

1.) *Hypochlorous acid* is a combination of two measures or one atom of chlorine with one atom of oxygen ($Cl\,O$), and it is characterized by its power of destroying all vegetable çolors. It is resolved with great ease into free chlorine and oxygen. It is the *bleaching* principle of the well-known *chloride of lime.*

2.) *Chloric acid* consists of one atom of chlorine and five atoms of oxygen; thus its formula is $Cl\,O_5$. As it is so rich in oxygen, and releases it very readily when heated, its salts are frequently employed for obtaining oxygen, or for combining other substances with oxygen (oxidizing them). The salt of this kind most commonly employed is the chlorate of potassa, which was used in some of the earlier experiments.

3.) *Perchloric acid* is a combination of one atom of chlorine and seven atoms of oxygen.

Bromine and *iodine* comport themselves like chlorine, and combine with oxygen, forming acids, which are easily decomposed. Fluorine does not unite at all with oxygen.

CYANOGEN AND OXYGEN.

179. *Cyanogen,* although composed of two elements (carbon and nitrogen), comports itself, nevertheless, exactly like a simple body, and, moreover, like a salt-former, and can form several acids with oxygen. Two of these are of great interest in a scientific point of view, because they have quite the same constitution, but entirely different properties. They consist of equal atoms of cyanogen and oxygen. One of them is called *fulminic acid* ($Cy_2\,O_2$), and is united with the oxide of mercury in fulminating mercury, and with the oxide of silver in the fulminate of silver. The well-known percussion-caps afford a familiar example of the violence with which these salts explode, on being rubbed or struck by some hard body. One of these caps contains only one third of a grain of fulminate of mercury. The fulminic acid separates, on exploding, into two gases, nitrogen and carbonic oxide, which suddenly occupy a space several thousand times *greater than* before. The second acid

is called *cyanic acid* (Cy O); it likewise decomposes very readily, but without explosion or danger.

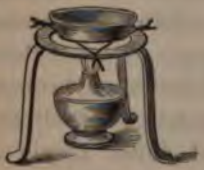
Bodies which contain just the *same* constituents, and in exactly the same quantity, but at the same time are quite *dissimilar* in their properties, are called *isomeric* (from ἴσος, *equal*, and μέρος, *part*), or similarly constituted bodies.

BORON AND OXYGEN.

Boracic Acid, BO_3.

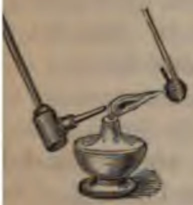
180. *Experiment.* — Dissolve in a porcelain dish half an ounce of borax in an ounce and a half of boiling water, and add muriatic acid by drops to the solution, until the liquid gives a strong acid reaction; on gradually cooling, the boracic acid will separate in scaly plates, which are purified by being again dissolved and recrystallized. Boracic acid is combined in borax with a base, soda; the stronger muriatic acid seizes upon this soda, and forms with it muriate of soda (or chloride of sodium and water), which remains dissolved, while the less soluble boracic acid separates from the liquid in crystals. There are some places in Italy where hot vapors containing boracic acid issue from the earth; large quantities of this acid are now obtained from these vapors, by conducting them into basins of water, where they condense with the boracic acid.

Fig. 97.



Experiment. — Take a piece of small platinum wire, about two and a half inches long, and bend one end of it into a hook; moisten this part with the tongue and dip it into boracic acid, so that a small portion of it may n adhering to the platinum. Now direct with the stream of air through the blow-pipe into the flame spirit-lamp, and approach the boracic acid to the point of the horizontal flame; it will first melt and swell in its water of crystallization into a spongy mass, but by continuous blowing will be converted into a transparent *glass bead.* Boracic acid does *not volatilize* on ignition. If you moisten the glass bead, and apply to it, either powdered chalk, litharge, or iron-rust, and again heat it to g, these substances will unite most intimately with oracic acid, and be dissolved by it, and likewise ed. Most of the combinations of boracic acids bases become *vitreous* on heating; that is, they together, forming sometimes a white, and some- a colored glass.

Fig. 98.



. The *blow-pipe* is an excellent instrument, on a scale, for volatilizing, heating to redness, melting, ing, or reducing substances. A double combus- akes place in the blow-pipe flame, in the interior ans of the air which is blown into it, and exter- by means of the atmospheric air. By this means, ones of light are formed, a smaller *interior* cone of color, and a larger *exterior* cone, of a yellowish rance; the former is called the *reducing flame*, the the *oxidizing flame*. If you wish to take oxygen body, — for instance, from an oxide, — hold it at int of the blue flame, where it meets with soot or , which combines with the oxygen of the oxide, g carbonic acid. *But if, on* the other hand, a body is to be oxidized, then it is held at the point of the outer flame, where the oxygen of the air can have free access to it. In order to acquire a practical knowledge of the blow-pipe, first attempt to convert a piece of lead, placed upon charcoal, into an oxide, by exposing it to the outer flame; and afterwards to restore this oxide to its original metallic state, by exposing it to the inner flame, in order to reduce it. The habit must, moreover, be acquired, of breathing through the nose while blowing, and to do this the cheeks must be kept constantly distended. When this habit is acquired, the chest is no longer strained by blowing, and a long uninterrupted stream of air may be kept up.

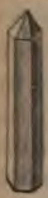
182. *Experiment.* — If you mix some boracic acid in a mortar with alcohol, and kindle the latter, it will burn with a *green flame.* In this way boracic acid may easily be detected. Some of the acid, though not volatilized by heat, as shown in a previous experiment, escapes with the alcohol. Other bodies also exhibit a similar inconsistency; when heated by themselves, they are completely non-volatile, but they volatilize, and frequently at very low temperatures, *when they find themselves in company with another body which is very volatile.* Thus, in the present instance, the alcohol is the occasion of the volatilization of the boracic acid. Hot steam will also render large quantities of non-volatile silicic acid volatile, and carry it off with itself. Common salt is constantly taken up by the vapors which rise from the ocean into the air; it is again precipitated with the rain, and in this manner is diffused over the whole earth.

Boracic, like phosphoric acid, is, in the moist condition, a very weak acid, but at a glowing heat it is one of the strongest acids.

SILICON AND OXYGEN.

Silicic Acid, or Silica (SiO_2).

Fig. 99.



183. That which is commonly called flint is called in chemistry *silicic acid*. We find it tolerably pure in quartz and flint, and in rock crystal often beautifully crystallized in six-sided prisms, or six-sided pyramids, and so transparent, that ornamental stones, the so-called Bohemian diamonds, are made from it. The red cornelian, the violet amethyst, the green chrysoprase, the variegated agate and jasper, the opal and chalcedony, — these well-known precious stones consist, likewise, of silica; their colors are chiefly owing to the presence of metallic oxides. Common sand is rendered, by hydrated oxide of iron, yellow or brown colored silica. In its natural state, silica is so hard as to give sparks with steel, and is quite insoluble in water and acids, except hydrofluoric acid. It may, perhaps, seem astonishing to some, that such bodies as our common sand, or flint, should be included among the acids. The reason is, that silica, just like other acids, combines with bases, and forms salts.

Experiment. — Boil in a porcelain vessel one drachm of finely ground sand and two drachms of caustic alkali, with one ounce of water, for some hours, supplying the water, occasionally, as it evaporates; then let the mixture stand in a closed vessel, for the impurities to settle. Part of the sand dissolves in the alkali, and forms with it a thickish opalescent mass. If you add muriatic acid to this solution, a thick gelatinous precipitate of silicic acid will be formed. If, on the contrary, you previously dilute the liquid with from ten to twelve *times its quantity of* water, and then remove the potassa by muriatic acid, the liquid will remain clear, and the silicic acid remain dissolved in the water. But this solubility is destroyed as soon as the liquid is evaporated to dryness, and the silicic acid is then thrown down as a white powder, which is completely insoluble in water. Thus, as is obvious, silicic acid exists also in two quite dissimilar isomeric modifications, one *insoluble*, as occurring in siliceous stones and rocks; and another *soluble*, as found in plants and water.

Almost all our springs, as well as our plants, contain small quantities of silicic acid. If we evaporate spring-water, we find silica in the insoluble residuum; and if we burn a plant, we obtain it in the ashes. Grasses, and the different sorts of grain, are particularly rich in silica, and for this reason they have been called *siliceous plants*. Silica is to these plants what bones are to men, — the substance to which the stalk owes its firmness and stiffness. If the soil is deficient in soluble silica, these properties will be wanting to the stalk, and it will bend over. The horse-tail plant (Equisetum) contains so much silica that it may be used for polishing wood. Silicic acid is found even in the animal kingdom, particularly in the class of Infusoriæ, which are only visible under the microscope; the shells of many Infusoriæ are formed of silicic acid.

The combination of silicic acid with bases may be effected more completely by *fusion*. Most of the silicates thus obtained are *amorphous*, and are said to be vitreous. Silicic acid has in this respect the greatest resemblance to boracic acid, and it also resembles it in being an extremely feeble acid in its moist state; but when heated, on account of its non-volatility, it surpasses all other acids in strength. In its isolated state, silicic acid can be melted only by the heat of the oxy-hydrogen blow-pipe.

RETROSPECT OF THE OXYGEN ACIDS.

1. Most of the combinations of the metalloids, or non-metallic elements, with oxygen, are *acids* (acid oxides).

2. Most of the combinations of the metals with oxygen are *bases* (basic oxides).

3. The acids *redden* blue test-paper, the bases color the red paper *blue* (when they are soluble).

4. The acids have an *acid* taste, and the bases an *alkaline* taste (when they are soluble).

5. When acids and bases combine together, the acid as well as basic properties are destroyed (neutralization), and new compounds are formed, *salts;* these have a brackish taste if soluble in water, but are tasteless if insoluble in water.

6. The principal characteristic of the acids is, *that they combine with bases, forming salts;* therefore we class all bodies which do this among the acids, even if they do not possess an acid taste or reaction. The same rule applies conversely to the bases.

7. Most of the acids, in the state in which they are commonly obtained and employed, are chemically combined with a fixed quantity of *water* (hydrates). Many acids cannot exist without water (water of constitution). By adding more water, we obtain the *diluted acid.*

8. One and the same element often forms several acids, with unequal, but always fixed, quantities of oxygen.

9. The acids have an unequal affinity for bases;

dry condition), mostly *stronger*, but
peratures (in the moist condition) *we*
atile acids. The strength of the affi
varies according to the temperature.

11. The acids just considered are
sense *oxygen acids*, because they co
owe to it their acid properties.

12. The combinations of oxygen ac
called *oxy-salts*.

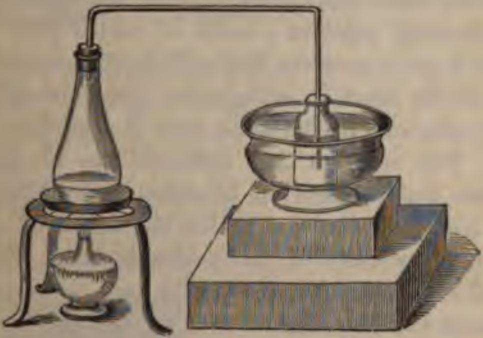
SECOND GROUP: HYDRACIDS, OR CO THE HALOGENS WITH HYD

184. As oxygen combines with the
ing acids, so also hydrogen can conv
into acids. *The five halogens — chlo*
dine, fluorine, and cyanogen — are acid
Oxygen, as has been shown, is able
acids with one and the same metall
with sulphur it forms sulphuric and s
with nitrogen, nitric and nitrous acid

phuric acid; there escapes, with effervescence, a gas, which has a pungent odor, an acid taste, and reddens moistened blue test-paper; this gas is *muriatic acid*, or *hydrochloric acid*. If you pour some ammonia upon a shaving, and wave the latter to and fro over the capsule, a thick white smoke is formed; and the acid odor of the muriatic acid, and also the pungent fumes of the ammonia, vanish. The acid fumes are neutralized by the volatile base contained in the ammonia; there is formed an odorless salt (chloride of ammonium), and in such a minute state of subdivision, that it floats in the air. We can, in this way, easily determine whether the air contains muriatic acid, or, by reversing the experiment, whether it contains ammonia, and also deprive these gases of their suffocating and injurious properties, and remove them from the air.

Experiment. — Mix carefully in a flask a quarter of an ounce of water with three quarters of an ounce of sulphuric acid, and after the mixture has become cold, add to it half an ounce of common salt. Adapt to the neck of the flask a cork provided with a glass tube, the long limb *of which passes into* a phial, containing

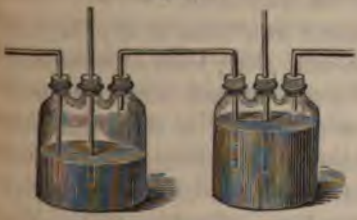
Fig. 100.



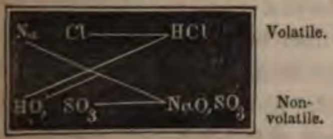
phial, the whole liquid might sud
the flask, if the heat should cha
might, for instance, from the flicke
by an accidental current of air. T
eagerly absorbed by the water, tha
of the gas diminishes, a vacuum i
and flask; the exterior air then
upon the water and forces it up (§
ous body condenses into a liquid,
the latent heat by which it beca
therefore this heat is set free. Fro
the water in which the muriatic a
solves must soon become warm.
receive much less gas than cold;
to obtain a concentrated solution
must place the phial in a basin o
the liquid in the receiver has suffi
of the blocks must be withdrawn
to keep the end of the tube nea
liquid. The solution thus obtai
acid taste and reaction; it is call

The muriatic acid of commerce is commonly yellow, and contaminated with sulphurous acid, sulphuric acid, chlorine, iron, and sometimes even with arsenic. Muriatic acid is likewise manufactured from common salt and sulphuric acid; but, instead of glass vessels, large iron cylinders are employed, capable of containing some quintals of common salt. The gas is conducted into several bottles or jars, connected with each other, and which are filled with water. When the water in the first vessel becomes saturated with hydrochloric acid, the gas passes over into the second, then into the third vessel, and so on, saturating each successively. This is a very convenient method of conducting gases through liquids. Such vessels, which are commonly provided with two or three necks, are called *Woulfe's bottles.* The upright tube in the middle neck serves as a safety tube, that is, it prevents the liquid from being forced back; if a vacuum is formed in one of the bottles, the air enters through this tube.

Fig. 101.



Common salt consists of chlorine and sodium; if water is added to it, the chlorine will abstract from it hydrogen, and the sodium oxygen, and muriate of soda is formed. This is decomposed by the more powerful sulphuric acid, which combines with the base, and expels the hydrochloric acid. The *sulphate of soda* (Glauber salts)



remains behind as a white salt, and is used in the manufacture of the important article, carbonate of soda.

The constituents of muriatic acid gas are equal atoms of chlorine and hydrogen, and it is represented by the symbol H Cl.

If you fill a jar half with chlorine and half with hydrogen, and put it in a dark place, no union ensues; but it takes place instantaneously when the jar is exposed to the direct rays of the sun. The union is accompanied by a violent detonation, which often breaks the glass, so that it is not advisable to perform this experiment. But it proves that light also compels some substances to combine chemically with each other.

186. *Experiments with Muriatic Acid.*

Experiment a. — Put some iron nails in a phial, and pour upon them some muriatic acid; brisk effervescence will ensue. When this has continued some minutes, hold a burning taper over the mouth of the phial; the gas which escapes inflames; it is hydrogen. The muriatic acid is decomposed, and its second constituent, chlorine, combines with the iron. The iron disappears, and it dissolves; that is, it combines with the chlorine, forming a soluble compound. When the effervescence has ceased, heat the phial by placing it in hot water, and afterwards pour its contents on a filter of white blotting-paper. Put the liquid which passes through (*the filtrate*) in a cool place; a salt is deposited from it in greenish crystals, called *protochloride of iron* (Fe Cl), that is, iron united with chlorine.

Many other metals may also be dissolved, like iron, in muriatic acid, and converted into salts.

Experiment b. — Pour some muriatic acid upon iron-rust that has been put into a test-tube; it dissolves, but without evolution of gas. In this case, the hydrogen of the muriatic acid meets with a body with which t can combine, namely, the oxygen of the oxide of iron; and it does combine with it, forming water. The yellowish-brown solution, which it is difficult to crystallize, yields, upon evaporation, a brown mass called *sesquichloride of iron* (Fe_2Cl_3). This salt contains one half more chlorine than the former. Muriatic acid is very often used for dissolving metallic oxides.

Experiment c. — Dissolve some crystals of the protochloride of iron, obtained according to experiment *a*, in a little water, and then add some chlorine water; the greenish color is converted into a yellow color, and the solution yields, on evaporation, brown *sesquichloride of iron.* The chlorine combines with the protochloride of iron, and makes it sesquichloride of iron.

Experiment d. — Dissolve some carbonate of soda in water; the solution turns red test-paper blue; it has a basic reaction. Drop carefully into the solution some nuriatic acid, until neither the red nor the blue paper is ffected by it. Thus muriatic acid, just like an oxygen cid, has the power of neutralizing bases. If you put he liquid in a warm place, a salt will be deposited in mall cubes; you readily perceive, both by the shape of he crystals and by the taste, that it is common salt. Here also the oxygen of the base has combined with he hydrogen of the muriatic acid, forming water, but he chlorine with the sodium, forming common salt. The carbonic acid of the carbonate of soda escapes with ffervescence.

Experiment e. — If you drop into a test-tube some nuriatic acid, and then a few drops of a solution of nirate of silver (lunar caustic), a white cloudiness is ormed, which does not happen in pure water. This loudiness proceeds from the chloride of silver, which is insoluble in water. Nitrate of silver is the most accurate test for muriatic acid and its salts.

If muriatic acid is diluted with from 800 to 900 parts of water, and is poured upon land, it exhibits a fertilizing power, like that of sulphuric acid (§ 173).

187. *Haloid Salts.* — Like chlorine, the other salt producers, or halogens, also combine with metals forming salts; these salts are called *haloid salts*. As has been shown, they may be prepared, —

1.) By uniting a halogen with a metal (§ 156).

2.) By uniting a halogen with a metallic oxide (§ 152).

3.) By the solution of a metal in a hydrogen acid (§ 186).

4.) By the solution of a metallic oxide in a hydrogen acid (§ 186).

If the two last-mentioned instances be attentively considered, it may, perhaps, appear surprising why it was not assumed that muriatic acid combined with the base without further decomposition, just as it was assumed with regard to sulphuric acid, and the other oxygen acids. This cannot generally happen, because many of the haloid salts, when they are quite dry, contain neither oxygen nor hydrogen. Completely dried common salt, for example, contains no hydrochloric acid, but chlorine, — no oxide of sodium, but sodium, — as has been ascertained by the most accurate experiments. But if the haloid salts contain water, or are dissolved in water, then they may certainly be regarded as consisting of a base and a hydrogen acid, for it amounts to the same thing, whether the hydrogen exists in the water or in the hydrogen acid, the oxygen in the water or in the metallic oxide. A solution of salt may accordingly be regarded as chloride of sodium and water, or as *muriate of soda*. ($NaCl + HO$ is the same as NaO, HCl.)

Formerly the combinations of chlorine with the metals were universally called *muriates.* The names, muriate of lime, muriate of baryta, muriate of oxide of iron, &c., have therefore the same signification as chloride of calcium, chloride of barium, chloride of iron, &c. When chlorine combines with a metal in several proportions, the combination with less chlorine is called protochloride, that with more chlorine, sesquichloride, and that with still more chlorine, perchloride (§ 154). If water is contained in them, or if they are dissolved in it, the protochlorides may be regarded also as *protomuriates,* and the perchlorides as *permuriates;* for example,—

Protochloride of iron and water is the same as protomuriate of oxide of iron.

$$(\mathrm{Fe\,Cl} + \mathrm{H\,O} = \mathrm{Fe\,O}, \mathrm{H\,Cl.})$$

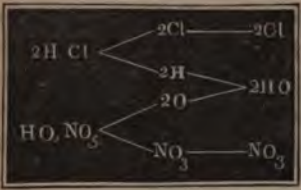
Sesquichloride of iron and water, the same as the muriate of the sesquioxide of iron.

$$(\mathrm{Fe_2\,Cl_3} + 3\,\mathrm{H\,O} = \mathrm{Fe_2\,O_3} + 3\,\mathrm{H\,Cl.})$$

AQUA REGIA, OR NITRO-MURIATIC ACID ($2\,\mathrm{H\,Cl} + \mathrm{N\,O_5}$).

188. *Experiment.* — Put into a flask one drachm of nitric acid, and into another two drachms of pure muriatic acid, and add to each some genuine gold-leaf; it will not be dissolved. But if both liquids are mixed together, the gold very soon disappears, because it is dissolved. Gold is deemed the king of metals, hence the name *aqua regia.* On evaporating this solution, a yellow salt remains behind, which consists of gold and chlorine. As the muriatic acid did not voluntarily give up its chlorine to the gold, it is highly probable that it was compelled to do so by the nitric acid. This process may be easily explained, if we refer to the preparation of chlorine from muriatic acid and hyperoxide of manganese.

The nitric acid acts upon the muriatic acid just like the manganese; it contains, like the latter, much oxygen, and parts with it very readily. This happens also in the present case, and the liberated oxygen abstracts from the muriatic acid its hydrogen, to form water. Consequently the chlorine is set free, which, being a simple and strong chemical body, immediately unites with the gold, which is likewise a simple body. The nitric acid loses thereby two atoms of its oxygen, and is converted into nitrous acid, which escapes in yellowish fumes.



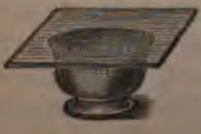
Aqua regia is employed for dissolving gold and platinum, neither of which metals is attacked by other acids.

BROMINE, IODINE, AND FLUORINE, + HYDROGEN.

189. *Hydrobromic and Hydriodic Acids.* — Both of these acids closely resemble muriatic acids. Their combinations with metals are called protobromides, perbromides, protoiodides, and periodides, &c., of the metals. They occur in nature accompanying common salt, consequently in sea-water and marine plants, in salt springs, &c., but only in minute quantities.

190. *Hydrofluoric Acid.* — *Experiment.* — Rub to a powder a piece of fluor-spar, of the size of a hazle-nut, and put it into a small bowl, which has been previously rubbed with oiled paper; then pour sulphuric acid upon it till a thin paste is formed. Cover the bowl with a piece of window-

Fig. 102.



glass, which has received a coating of wax, and from some parts of which the wax has been removed by scratching with a needle, or other pointed instrument. After the lapse of some hours, remove the wax by melting it, and then rubbing it off with oil of turpentine; those parts of the glass left bare will be found to be *corroded.*

Fluor-spar consists of fluorine and calcium, and is decomposed by sulphuric acid, in the same manner as common salt was; hydrofluoric acid is formed and escapes in vapor. This acid has the property of dissolving *silica;* therefore it withdraws the latter from the glass, where it is not protected by the wax, and the glass consequently becomes rough and opaque. In this manner drawings are often etched on glass. By conducting the fumes into water, liquid hydrofluoric acid is obtained, which may likewise be employed for etching on glass. Lead or platinum vessels must be used in the preparation of it, on account of its property of corroding glass and porcelain.

We also find fluoride of calcium, in small quantities, in the bones and teeth of the Mammalia.

CYANOGEN AND HYDROGEN, HYDROCYANIC ACID ($H\,Cy$).

191. The great similarity which *Cyanogen*, composed of carbon and nitrogen, has to the halogens, is also manifested by its combining with hydrogen, forming an acid. This combination is the notorious *prussic* or hydrocyanic acid, a few drops of which are sufficient to kill instantaneously a small animal. As muriatic acid is obtained from chlorides by sulphuric acid, so prussic acid is also obtained from the cyanides by means of sulphuric acid, and it is also gaseous, like muriatic acid. To obtain it in a liquid form, the gas is

conducted into water, or alcohol, by which it is absorbed. It is colorless, like water, and it is easily recognized by its peculiarly oppressive odor, which is very similar to that of bitter almonds. Such a dangerous article should only be prepared by experienced workmen. Prussic acid is found also in small quantities in some seeds, particularly in bitter almonds, and in the kernels of stone fruits, as plums, apricots, &c.

Prussic acid combines with bases, forming water and metallic cyanides (protocyanides and percyanides). The most familiar of these are the yellow ferrocyanide of potassium (prussiate of potassa), and the blue ferrocyanide of iron (prussian blue).

RETROSPECT OF THE HYDROGEN ACIDS.

1. The haloids or halogens — chlorine, bromine, iodine, fluorine, and cyanogen — form *acids*, not only with oxygen, but also with *hydrogen*.

2. The halogens have a greater preference for *hydrogen* than for oxygen; hence, when left to their own free will, they always combine with the former.

3. Hydrogen unites with the halogens only in *one proportion;* consequently, each of them forms only one single hydrogen acid.

4. All the hydrogen acids have the same constitution; they always consist of *equal* atoms of a halogen and hydrogen.

5. The hydrogen acids combine with metals, forming chlorides, bromides, &c., whilst their hydrogen escapes.

6. The combinations of the halogens with the metals possess exactly the properties of salts; for this reason they are called *haloid salts.*

7. The hydrogen acids combine with the bases, forming haloid salts and water.

8. If water is present in the haloid salts, they may be regarded as combinations of the hydrogen acids with bases, or as hydrogen acid salts, just as the oxygen salts are regarded as combinations of oxygen acids with bases.

9. Many metals may combine with the halogens in several, generally in two, proportions. When the halogen is in excess, they are called perchlorides, perbromides, &c.; but when deficient, they are called protochlorides, protobromides, &c. The former correspond with the peroxide salts, the latter with the protoxide salts.

RETROSPECT OF THE COMBINATIONS OF THE METALLOIDS WITH OXYGEN AND HYDROGEN.

192. The combinations which *hydrogen* forms with the halogens have been here grouped together, because they have the greatest similarity to each other. These combinations possess the distinctive character of strong acids. The other metalloids can also combine with hydrogen, but they do not form acids with it, sulphur alone being an exception, the combination of which with hydrogen certainly comports itself like an acid, though only as a very feeble one (§ 132). The contrary occurs with nitrogen; this forms with hydrogen a base, ammonia. The combinations of the other metalloids with hydrogen, some of which have already been treated of under the separate metalloids, exhibit neither basic nor acid properties; they are, on this account, called neutral or indifferent bodies. Oxygen and hydrogen constitute the indifferent body, water; carbon and hydrogen, the indifferent illuminating and marsh gas; phosphorus and hydrogen form phosphuretted hydrogen, also an indifferent body.

The combinations which *oxygen* forms with the non-metallic elements, or metalloids, are, indeed, mostly acids, but we find among them some which possess an *indifferent* character; namely, nitrous and nitric oxides (NO and NO_2), the oxide of phosphorus, and carbonic oxide gas (CO). As is obvious, the combinations with the *least* quantity of oxygen are those in which the acid properties are wanting; these acid properties are developed on the increase of the oxygen, and most strongly in those combinations which contain the greatest quantity of oxygen.

Since the combinations which the metalloids form, on the one side with oxygen, and on the other with hydrogen, are among the most important and most interesting chemical bodies, the annexed scheme will present nearly a correct idea of the strength of the affini-

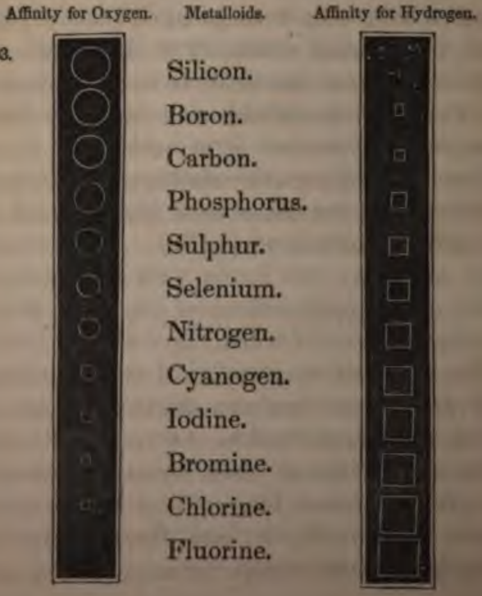


Fig. 103.

ties which each of the metalloids possesses for these two elements. The size of the circles represents the affinity for oxygen, that of the squares the affinity for hydrogen. From this it is apparent that the partiality of the metalloids for hydrogen increases in proportion as it diminishes for oxygen, and the reverse.

THIRD GROUP: ORGANIC ACIDS.

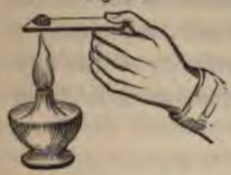
193. The oxygen and hydrogen acids are commonly called inorganic or mineral acids, because they are principally found in the mineral kingdom, or prepared artificially from minerals and earths. But there are, besides, many other acids, found either already existing in animals and plants (formic acid, citric acid), or which may be artificially produced from organic substances (lactic acid, acetic acid). Such acids are called *organic*, or vegetable and animal acids. They have the greatest similarity to the inorganic acids in their properties and combinations, but not in their constitution. Three of them only will be treated of at present as examples of this class of acids, one a volatile, and the other two non-volatile acids; the others will be considered in the second and third parts of this work.

TARTARIC ACID ($HO, \bar{T}$).

194. Tartaric acid has very much the appearance of a salt; it crystallizes in colorless oblique prisms, which are permanent in the air and have a very acid taste.

Experiment. — Place a small crystal of tartaric acid upon a piece of platinum foil, and heat it over the flame of a spirit-lamp; it will first melt, then become brown, and finally black, and emit at the same time a peculiar

Fig. 104.



empyreumatic odor. If, during the process of charring, you hold over the acid a dry, cold glass vessel, it will become lined with globules of water; consequently the acid contains oxygen and hydrogen. The dark residue resembles coal, but it is more certainly determined as such by its burning completely at a higher heat. Accordingly, tartaric acid has, when heated, the greatest similarity to burning wood. In fact, it consists of the same elements, namely, carbon, hydrogen, and oxygen, but in different proportions. *All vegetable acids consist of* C, H, *and* O, *and are charred and consumed on being heated.* By these two characteristics the organic acids are essentially distinguished from the inorganic, which consist only of two elements, and which are neither charred nor consumed in the fire.

Experiment. — Pour a little warm water over some tartaric acid; it will dissolve therein, for it is *readily soluble* in water. If you dilute the solution with more water, and put it aside in a moderately warm place, slimy flakes will be deposited, and the acid taste will gradually be lost,—it *putrefies.* In a similar manner, all organic acids, when they are diluted with water, decompose after a time.

Experiment. — Mix gradually a solution of tartaric acid with ammonia; there will be a period when the acid properties of the tartaric acid and the basic ones of the ammonia will have disappeared. Accordingly, tartaric acid, just like other acids, can neutralize bases, and form with them salts. The tartrate of ammonia obtained is easily soluble.

Experiment. — Neutralize a solution of carbonate of *potassa* with a solution of tartaric acid; the carbonic acid escapes; the liquid, however, remains clear, because the neutral tartrate of potassa ($\mathrm{K\,O}, \bar{\mathrm{T}}$) formed is an easily soluble salt. But by adding yet more tartaric acid, the liquid becomes turbid, and deposits a quantity of small, transparent crystals, which are difficultly soluble in water, have an acid taste, and contain twice as much acid as the neutral salt, besides, also, some water of crystallization. These crystals are called acid tartrate of potassa, or bitartrate of potassa ($\mathrm{K\,O}, 2\,\bar{\mathrm{T}} + \mathrm{H\,O}$); commonly, tartar, or when they are pulverized, cream of tartar. The salts of potassa may accordingly be used as a *test for tartaric acid.*

Tartaric acid is generally prepared from tartar or argol, which is obtained in large quantities from the wine countries, where it is deposited from wines in their fermenting casks, as a white or reddish crust. The potassa might be very easily removed from this salt by means of sulphuric acid; but then two soluble substances would be obtained, which could not well be separated from each other. For this reason, the potassa is first replaced by another base, namely, by lime, which forms with sulphuric acid an insoluble, or at least very difficultly soluble compound. By boiling tartar with water, and adding chalk to it, then *tartrate of lime* is obtained, as a white insoluble powder; if this, after being sufficiently washed, is put by for some time with water and sulphuric acid in a warm place (digested), the latter unites with the lime, and forms gypsum, whilst the tartaric acid, being set free, dissolves in the water, and crystallizes from the solution after evaporation.

The chemist is often obliged to resort to such circuitous means in order to separate two bodies from each other, both of which are equally soluble in water or in some other liquid.

Experiment.—If you heat the crystalline powder of tartar, obtained in the former experiment, on platinum foil, it will, like the tartaric acid, become black, and is consumed, emitting an empyreumatic odor; but there will, however, finally remain a white powder, which has an alkaline taste, a basic reaction, and which, on the addition of an acid, will effervesce like carbonate of potassa. The acid burns up, but not the alkali; on the combustion of the acid, carbonic acid is formed, which combines with the potassa; consequently, carbonate of potassa is formed. All salts of the alkalies, or alkaline earths, with an organic acid, are in the same way decomposed by heat, and converted into carbonates.

195. We can decompose sulphuric acid into sulphur and oxygen; and from sulphur and oxygen we can again reproduce sulphuric acid. Not so, however, with tartaric acid; we may succeed in demolishing it, but it is beyond our power to reproduce it again. *We cannot artificially produce the organic acids from their elements.* We are still ignorant how they are formed in plants and animals. All that is known on this point concerning the vegetable acids is, that they are formed from carbonic acid and water, the two chief sources of the nourishment of vegetables. But by what power, and in what manner, these two bodies are forced to combine in the grape-vine to form tartaric acid, in the fruit of the lemon-tree to form citric acid, in apples to form malic acid, &c., we are entirely ignorant. We here stand, as it were, on the boundary line of our knowledge; whether it will be permitted to us at some future period to advance beyond this limit, further investigations must show. In the mean time we must assume that the unknown power which causes the shoots, *leaves,* and blossoms to put forth from the seeds,—we

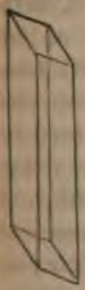
call it vital power, — is also able to produce chemical combinations and decompositions more powerful and manifold than it is possible for the chemist to accomplish in his retorts and crucibles. In this sense we regard the organic acids, as in general all organic substances, as the *chemical productions of the vital activity* of plants and animals.

The organic acids are briefly designated by a horizontal line placed above their initials. The Latin name for tartar is *tartarus;* the symbol for tartaric acid is $\bar{T}$.

OXALIC ACID (HO, $\bar{O}$, or HO, C_2O_3).

196. *Experiment.* — Heat with free access of air, in a porcelain dish, one fourth of an ounce of sugar, mixed with one and a half ounces of concentrated nitric acid, and one ounce of water. In a short time a strong evolution of yellowish-red fumes (NO_3) will commence. Continue boiling until these vapors cease, and then put the liquid in a cool place; colorless crystals (right rhombic prisms) will be separated, which must be purified by recrystallization. They have an intensely strong acid reaction, and are poisonous; they are called *oxalic acid.* This acid, like most acids, contains water chemically combined, without which it cannot exist.

Fig. 105.



Experiment. — Pour into a test-tube twenty grains of oxalic acid, and one drachm of fuming oil of vitriol, and carefully heat the mixture; a gas will be evolved. Let this pass through lime-water contained in another test-tube. One half of the escaping gas is absorbed by the lime-water, which thereby becomes turbid; this is carbonic acid (CO_2). The *other half* escapes through the open tube, and burns, when kindled, with a bluish flame; this is carbonic oxide gas (CO). When the evolution of the gas ceases, there will be found in the first test-tube common sulphuric acid; consequently, the fuming oil of vitriol has received water, namely, the chemically combined water contained in the oxalic acid. The oxalic acid, when it loses its water, is resolved into the two gases just mentioned; it may, accordingly, be regarded as a combination of

$$\begin{array}{rr} & 1 \text{ atom } CO_2, \\ \text{and} & \underline{1 \text{ atom } CO,} \\ & \text{or } \; C_2O_3. \end{array}$$

On comparing this constitution with that of sugar, it will be seen that the sugar contains still more carbon than the oxalic acid, besides some hydrogen; consequently a portion of its carbon, and all its hydrogen, must have been withdrawn. This was done by the oxygen of the nitric acid, which oxygen, uniting with the carbon, formed carbonic acid, and with the hydrogen, formed water. This process may be regarded as a combustion (oxidation) in the moist way. Sugar has exactly the same constituents as wood. If a wood-shaving be ignited, at first the hydrogen principally burns, because it is very readily combustible; at last principally the carbon, because this burns with more difficulty (§ 120). The same succession of phenomena also takes place on the boiling of sugar with nitric acid; the hydrogen is at first principally oxidized, and afterwards the carbon; but the latter only partially, on account of the insufficient supply of nitric acid, just as wood is only partially consumed when there is a deficiency in the supply of the air. The partly consumed wood (charcoal) burns completely if we heat it still *longer in* the air; it is converted into carbonic acid by the oxygen of the air. Partly burnt sugar (oxalic acid) consumes completely when we boil it with still more nitric acid; it is converted into carbonic acid by the oxygen of the nitric acid.

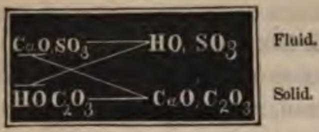
197. *Experiments with Oxalic Acid.*

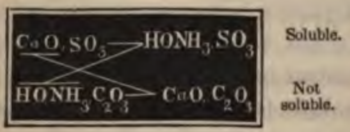
Experiment a. — Place some crystals of oxalic acid upon a piece of platinum foil, and hold them in the flame of a spirit-lamp. They melt, inflame, and burn *without becoming black* or leaving any residue. The product of the combustion is carbonic acid; $C_2 O_3$ and O (from the air) are converted into $2\,C\,O_2$.

Experiment b. — Neutralize a hot concentrated solution of oxalic acid with a hot concentrated solution of carbonate of potassa; neutral oxalate of potassa ($K\,O, C_2 O_3$), an easily soluble salt, is formed. If you now add as much more oxalic acid, hard crystals will be deposited on cooling, which have an acid reaction; they are called acid oxalate, or binoxalate of potassa. One atom of potassa can thus combine with two atoms of acid. As has been previously stated, salts with two atoms of acid are called *acid salts*. The binoxalate of potassa is likewise formed in the substance of many plants during their growth, and it is found abundantly in the leaves of the wood-sorrel (Oxalis), from which it may be obtained. The acid salt is far less soluble than the neutral.

Experiment c. — Heat some binoxalate of potassa upon platinum foil; like the tartar, it will be converted into carbonate of potassa, but *without being charred or blackened*. The oxalic acid is thereby converted, as above, into carbonic acid and carbonic oxide, and a portion of the former combines with the potassa.

Experiment d. — Agitate a little gypsum with water and let the liquid settle; the decanted water contains a small quantity ($\frac{1}{500}$) of gypsum in solution. If a solution of oxalic acid is poured upon this solution of gypsum you will soon obtain a precipitate of oxalate of lime consequently oxalic acid has a greater affinity for lime than sulphuric acid has, since it is able to displace the latter acid. The decomposition takes place more rapidly and perfectly when the oxalic acid has been previously neutralized by ammonia (NH_3), because another body is thus presented to the sulphuric acid, for which the latter has a greater affinity than for the water; it becomes thereby more ready, as it were, to release the lime. Oxalic acid is the best test for lime and lime salts.





Experiment e. — Add some spoonfuls of water to a piece of green vitriol of the size of a pea, and moisten with the solution a piece of white blotting-paper; when this has imbibed the liquid, spread over it some ammonia. The ammonia withdraws the sulphuric acid from the green vitriol, and protoxide of iron must consequently be separated in and upon the paper, to which it imparts a greenish tinge. On drying, the protoxide of iron becomes converted into sesquioxide of iron, and the green color is at the same time changed to yellow. In a similar manner, cotton, and other fabrics, are often dyed brown or yellow. Mix some oxalic acid with water into a thin paste, and dot the yellow paper with it in several places; the color will soon disappear from those spots, and you obtain a white pattern on a yellow ground. Oxalic acid easily dissolves se quioxide of iron, and both are removed by washing. Upon this is founded the important use of this acid in calico printing, as likewise its application for the removal of ink-spots from linen or paper. One of the principal constituents of ink is oxide of iron, which being dissolved by oxalic acid, the black color of the ink disappears also. This explains why oxalic acid, or an oxalate containing a free acid, causes the white spots on fabrics dyed yellow by peroxide of iron, and also why it removes ink-spots from garments, paper, &c.

ACETIC ACID ($HO, \bar{A}$).

198. Vinegar is likewise a vegetable acid. It is often formed spontaneously, producing mischievous consequences. It is formed when sweet or spirituous liquors, thin syrups, the juice of fruit, wine, beer, &c., remain exposed to the air. The sugar is converted by degrees into alcohol, which becomes vinegar when access to the oxygen of the air is not prevented. But the method by which this takes place will not be considered until sugar and alcohol are treated of. We shall now merely describe the method of preparing acetic acid from crude vinegar.

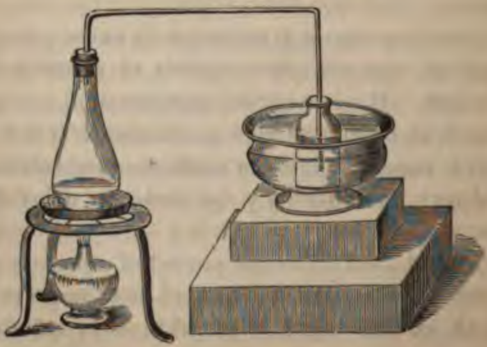
Our common vinegar contains in every pound only from half an ounce to two ounces of acetic acid; the rest is water. If you boil vinegar, the acid smell of the fumes indicates that the acid contained in it is volatile; therefore it cannot, like other acids, be made stronger by evaporation; but this may be done in the following manner.

Experiment.— Add to one pound of colorless vinegar from one to one and a half ounces of litharge (oxide of lead), and let the *mixture stand* in a vessel for some hours, in a warm place, stirring it frequently. The liquid will become clear on standing, and then if you evaporate it down to two and a half or three ounces, and let it cool, prismatic crystals of *acetate of oxide of lead* will be deposited. This salt is commonly called *sugar of lead* from its sweetish taste. The acetic acid is held so firmly by the oxide of lead, that it can no longer escape with the steam during evaporation, or at least only in trifling quantities. Other bases may be substituted for the oxide of lead.

Experiment. — Place upon a piece of charcoal some sugar of lead, and heat before the blow-pipe; the salt first melts in its water of crystallization, then it becomes brown, and is finally charred; the acetic acid is thus decomposed, like tartaric acid on the heating of the salts of tartaric acid. After being completely burnt, globules of metallic lead remain upon the coal. The litharge is also decomposed; the glowing coal abstracts from it its oxygen, and forms with it carbonic oxide gas, which escapes; consequently metallic lead must remain behind (reduction or deoxidation).

Experiment. — Mix cautiously half an ounce of sul-

Fig. 106.



huric acid with half an ounce of water, and when cold pour the mixture into a flask containing one ounce of pulverized sugar of lead. Now connect a glass tube and receiver with the flask, and distil the mixture at a moderate heat, on a sand-bath, until about three fourths of an ounce of the fluid has passed over. This presents an example of simple elective affinity; the strong sulphuric acid unites with the oxide of lead, and forms with it a white, insoluble compound, which remains in the flask, while the acetic acid, rendered volatile by the heat, is converted into steam, which is condensed in the cold receiver into liquid acetic acid.

The acid thus obtained is colorless, and has an exceedingly sour taste and smell. The strongest acetic acid (hydrated acetic acid) crystallizes on cooling; a somewhat diluted acetic acid is called concentrated vinegar.

Experiment. — Add to strong acetic acid some drops of oil of cinnamon and cloves; if the acid was sufficiently strong they will *dissolve.* This mixture is called aromatic spirit of vinegar.

Experiment. — Pour some acetic acid upon a piece of lean meat, and it will gradually become soft and gelatinous. Common vinegar has also the same effect, but in a less degree; it is indeed well known, that meat impregnated with vinegar becomes very tender and digestible (soluble) when boiled or roasted.

Acetic acid cannot exist without the presence of water; seven ounces of the strongest acid contain one ounce of water chemically combined. The Latin word for vinegar is *acetum;* the symbol for acetic acid is, accordingly, $H\,O,\,\bar{A}$.

To detect the salts of acetic acid, heat them in a test-tube with concentrated sulphuric acid; when fumes *having a very acid smell* will be evolved.

RETROSPECT OF THE VEGETABLE ACIDS.

1. Almost all vegetable acids consist of carbon, hydrogen, and oxygen (oxalic acid being an exception.)

2. They are generated during the growth of plants, in which they are found either free or combined with bases.

3. We cannot artificially prepare them from their elements, like the inorganic acids.

4. Some vegetable acids may indeed be also artificially imitated, but as a general rule this is effected by the metamorphosis of other vegetable substances.

5. All vegetable acids are charred by *heat*, and are at last completely consumed (inorganic acids are not).

6. Most vegetable acids cannot exist without the presence of *water;* this water plays therein the part of a base.

7. Vegetable acids comport themselves towards bases like the inorganic acids; they form with them *salts.*

8. The vegetable salts are likewise decomposed by heat; the acid is charred and consumed, while the base remains behind, usually combined with carbonic acid.

RADICALS.—CAPACITY OF NEUTRALIZATION.

199. The word *radical* signifies root or base, and is often employed in chemistry to denote that substance which is regarded as the fundamental element or base of a chemical compound. The metalloids unite with oxygen, and some of them also with hydrogen, forming acids, and they are consequently regarded as the bases of the acids, and may be called the *acid radicals.* Sulphur is accordingly the radical of sulphuric acid; carbon, of carbonic acid; and chlorine, of chloric and

muriatic acids, &c. With regard to the vegetable acids, which are composed of three elements, carbon, hydrogen, and oxygen, if the oxygen be assumed as the acidifying principle, then the carbon and hydrogen are regarded as the acid radicals; or if hydrogen be considered this principle, then carbon and oxygen would be the radicals. In either case the radical consists of two elements; and for this reason the vegetable acids are said to be *acids with a compound radical*, in contradistinction to the mineral acids, which are regarded as *acids with a simple radical*, because they have only one element for their base. According to this classification, the hydrocyanic and fulminic acids must be classed among the acids with compound radicals, since the radical cyanogen is composed of carbon and nitrogen.

This theory is also applied to bases and salts. The metals combine with oxygen, forming bases, and are accordingly the fundamental elements of the bases,—*basic radicals.* Iron, for example, is the radical of the oxide of iron, and calcium the radical of lime. The oxide or the base is regarded as the fundamental element of the salts; it has received the name *salt radical.* Protoxide of iron is accordingly the radical of green vitriol, lime that of chalk, &c.

200. It has already been demonstrated, by several experiments, that the acids are neutralized or saturated by bases, and also that every acid on neutralization combines with a definite quantity only of a base. It now remains to consider how large this quantity may be for every acid.

It has been ascertained, by accurate experiments, that 100 ounces of sulphuric acid require for neutralization exactly 118 ounces of potassa, or 70 ounces of lime, or 90 ounces of *protoxide* of iron, or 278 ounces of litharge. Further researches have led also to the surprising discovery, that these so unequal quantities of the different bases contain precisely the same amount of oxygen, namely, 20 ounces.

Sulphuric Acid			Oxygen.
100 oz. are neutralized by	118 oz. of potassa ;	these contain	20 oz.
100 " " " "	70 " " lime ;	" "	20 "
100 " " " "	90 " " protoxide of iron ;	" "	20 "
100 " " " "	278 " " oxide of lead ;	" "	20 "

It follows as a law for sulphuric acid, that 100 ounces of it require always for neutralization a quantity of some base in which are contained 20 ounces of oxygen. Thus the number 20 has been called the *capacity of neutralization* of sulphuric acid.

The action of bases upon all the other acids has been examined in the same manner, and the capacity of neutralization of the latter determined. That of nitric acid, for example, is 14¾; that of carbonic acid, 36¼; that is, every quantity of any base containing exactly 14¾ ounces of oxygen is able to saturate or neutralize 100 ounces of nitric acid; every quantity of a base containing 36¼ ounces of oxygen is able to saturate or neutralize 100 ounces of carbonic acid.

Instead of comparing, as has been done here, the *acids* with the oxygen of the base, the *oxygen of the acid* is also sometimes compared with the oxygen of the base. This may be done very easily, if we only know in the first place how much oxygen is contained in 100 ounces of an acid.

		Oxygen		Oxygen
100 oz. of sulphuric acid	contains	60	oz., and require in the base	20 oz.
100 " " nitric acid	"	73¾	" " " " "	14¾ "
100 " " carbonic acid	"	72½	" " " " "	36¼ "

And hence may be deduced the following simple proportion for the combination of the acids with the bases, *that is*, for the salts.

The *oxygen of the acid* bears the proportion to the *oxygen of the bases:* —

In all neutral sulphates, as 60 to 20, or as 3 to 1.
" " nitrates, " 73¾ " 14¾, " " 5 " 1.
" " carbonates, " 72½ " 36¼, " " 2 " 1.

Water acts also as a base when chemically combined with an acid. In common sulphuric acid ($H O, S O_3$), for example, the oxygen of the acid bears a proportion to the oxygen of the water as 3 to 1; in the strongest nitric acid ($H O, N O_5$), as 5 to 1, &c.

LIGHT METALS.

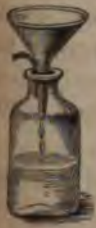
FIRST GROUP: ALKALI-METALS.

POTASSIUM (K).

At. Wt. = 489. — Sp. Gr. = 0.8.

201. *Potash, or Carbonate of Potassa* ($K O, C O_2$).

Fig. 107.



Experiment. — Fit into a funnel a filter of blotting-paper, and place upon it a handful of *wood-ashes*, and gradually pour hot water over them; the liquid filtered through has an alkaline taste, and turns red test-paper blue. If you evaporate it to dryness in a porcelain dish, a gray mass finally remains behind, which becomes *white* after being heated to *redness* in a porcelain crucible; it is called *crude potash.* In those countries where wood is abundant, — in America, Russia, &c., — it is prepared in a similar manner on a large scale, and is an article of great demand in commerce.

those which are insoluble (sil
unburnt pieces of coal) remain

Experiment. — Pour half an c
half an ounce of commercial p
and let it stand for one night.
filtration from the sediment, wh
of silica; evaporate it down t
leave it in repose for one night
eign salts will be deposited in
the liquid and evaporate to dryn
with a glass rod, and you will ob
mass, *purified potash.*

Potash is very easily soluble; t
the ingredients which is taken
last which is separated from it
tures are much less so, and the
solved, and partly separate in c
before the potash shows even th
crystallize. There are thus tw
substances of different degrees
separated from each other.

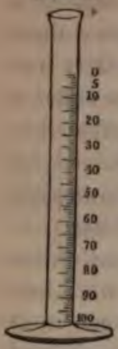
202. *Experiments with Potash.*

Experiment b. — Boil for some time, in a vessel containing a quarter of an ounce of potash and two ounces of water, a piece of gray linen, and some dirty or greasy linen or cotton rags; the liquid will become of a dark color, while the rags are made white and clean. Dirt, as it is commonly called, is dust, which adheres to the skin, garments, &c., particularly after they have become moistened by perspiration, or have come in contact with greasy or other adhesive substances. These last-mentioned substances may be dissolved and removed by potash; on this depends the various application of this substance in cleaning and washing.

Experiment c. — Pour a teaspoonful of potash into a tumbler containing vinegar; there escapes with brisk effervescence a gas, in which a burning taper is extinguished. This gas is the well-known *carbonic acid;* it is chemically combined in the potash with the basic *oxide of potassium or potassa.* Potash is consequently a salt, *carbonate of potassa* (KO, CO_2); but beside this, the crude potash contains also several other foreign salts, as silicate, sulphate, muriate, and phosphate of potassa, and many others. The feeble carbonic acid is not able to destroy completely the basic properties of the potassa; therefore the carbonate of potassa has an alkaline taste, and colors red litmus-paper blue. Vinegar can completely neutralize potassa. If you add so much of it to the potassa, that neither blue nor red test-paper is altered, and then filter and evaporate the liquid, you will obtain a white saline mass, — *acetate of potassa.*

We might suppose that the carbonic acid, which so willingly assumes a gaseous form, might easily be expelled by heating; but it is a striking fact, that its friendship for the potassa stands the proof even of the hottest fire. The potash does not lose its carbonic acid at the strongest red heat.

Fig. 108.



The potash of commerce possesses very different degrees of goodness and purity. To test its value, or to compare several sorts with each other, weigh one hundred grains of each sort, and neutralize them with an acid. A good article requires more acid than a bad one; consequently the value of the potash may be estimated according to the quantity of the acid consumed. An *alkalimeter* is a useful instrument for those who have frequently to determine the value of potash. It consists of a glass cylinder, divided into degrees (*graduated*), in which the quantity of acid is measured instead of being weighed. For this purpose a test-acid must be prepared, of such a strength that one degree of it will exactly neutralize one grain of pure carbonate of potassa. The number of degrees of the acid consumed will then indicate at once, in per cent., the quantity of pure carbonate of potassa in the sample tested. The value of soda may be ascertained in a similar way.

Bicarbonate of Potassa ($KO, 2CO_2 + HO$).

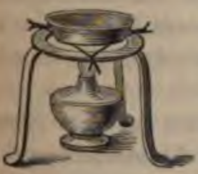
If carbonic acid is conducted into a solution of carbonate of potassa, the latter will take up as much again carbonic acid as it previously contained, and crystals will be deposited, consisting of one atom of potassa, two atoms of carbonic acid, and one atom of water. This combination belongs, accordingly, to the *acid salts*. On heating, the second atom of carbonic acid, together with the water, escapes; and the same happens, though more slowly, on boiling a solution of this salt.

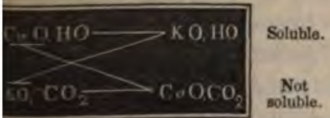
203. *Oxide of Potassium, or Potassa* (K O).

If you withdraw the carbonic acid from the potash, potassa remains behind.

Experiment. — Place half an ounce of quicklime in a plate, drench it with warm water, and let it stand until it is slaked, that is, until it becomes a fine dusty powder. Then put half an ounce of potash into an iron basin with six ounces of water, and boil it, and gradually add by spoonfuls, during the boiling, half of the slaked lime. After the mixture has boiled for some me, put a teaspoonful of it upon a paper filter, and ur the filtrate into vinegar. If it effervesces, still ore lime must be added; but if no effervescence enes, pour the whole into a bottle, close it up, and let it main quiet for some hours, that the sediment may bside. Decant the clear liquor, and preserve it in a ll-stoppered bottle. It consists of water in which tassa is dissolved, and is called *solution of caustic posa*, or lye. The carbonic acid previously combined with the potassa has during the boiling passed to the lime, as may easily be seen by the effervescence which enes when vinegar or some other acid is poured on e white sediment of lime. From the lime, carbonate lime is formed, but potassa from the carbonate of tassa. The carbonate of lime is insoluble, and is posited as a white powder; the potassa is soluble, nd it combines with the water present.

Fig. 109.





this acid even from a much
lime abstracts the carbonic ac
because it has a greater affin
cause it forms with it an inso
In the same way a weaker ac
come a stronger one.

Experiment. — Evaporate a
potassa in an iron vessel (gla
tacked by it); all the water bu
a white mass finally remains b
This may be melted at a stro
sticks or plates (*lapis infernali*

Potassa consists of a metal
(§ 166). It also contains on
water, which cannot be expell
heat; its proper name is, acco
sa (K O, H O). This water,
is chemically combined with
ing an indifferent body, acts
acid, and with strong acids lik

204. *Experiments with Hyd*

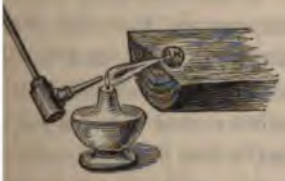
Experiment a. — Expose so
it will soon become moist:

a lye; both papers will be decomposed and dis- , the vegetable fibres of the white paper (linen or) more slowly than the animal fibres of the brown (wool). Potassa exerts a very *corrosive* action, ally on animal substances. The slippery feeling l by rubbing lye between the fingers is owing to ual solution of the skin.

eriment c. — Boil in a test-tube a little tallow or th a solution of caustic potassa; a union grad- akes place; soap is formed. The soap prepared otassa is soft, and is called barrel-soap or soft-

eriment d. — If some potassa be melted with sand on a piece of charcoal, before the blow-pipe, we obtain a vitreous, amorphous compound of silicate of potassa. Much sand and a small proportion of potassa yield an insoluble glass, — the common bottle or *window glass;* but much potassa with a proportion of sand, a soluble compound, called *glass.* A solution of the latter may be em- l as a fire-proof varnish for wood, canvas, and combustible materials.

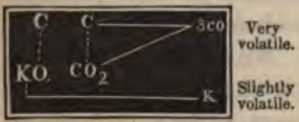
Fig. 110.



eriment e. — Dissolve a piece of blue vitriol (sul- of copper) in water, and add to it some potassa Potassa is the *strongest base* known; therefore it cts the sulphuric acid from the blue vitriol, and with it sulphate of potassa, which remains in n. The oxide of copper, not being soluble in

205. *Potassium*

If the oxygen is withdrawn
potassium remains behind, — a me
a tendency to combine again wi
only be protected against oxida
petroleum, a liquid which contai



The usual method of prepa
putti
sa an
vessel
exit-t
to the
At this extremely high temperatu
with the oxygen of the carboni
tassa, forming carbonic oxide gas
liberated potassium is also conve
is conducted into petroleum, whe
solid mass, resembling silver.

It has been shown under carb
potassium, at a moderate heat, c

a lively reddish flame. After the combustion is finished, the potassium has apparently vanished; but it is in fact in solution in the water, being, however, no longer potassium, but potassa, as we may easily ascertain by red test-paper, the color of which will be changed by the water to blue. Consequently it has, during the combustion, combined with oxygen; this oxygen it took from the water, and so much heat was thereby evolved that the second constituent of the water, hydrogen, was inflamed.

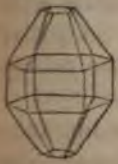
If a piece of potassium is divided with a knife, it presents a glistening surface like silver; but it immediately tarnishes on exposure to the moist air, and soon becomes converted into a white body, hydrate of potassa. In this case it takes the oxygen from the air.

Salts of Potassa.

Salts are produced, as has been before stated, when a base combines with an oxygen acid or a hydrogen acid (oxygen salts and haloid salts). As there are hundreds of acids, so also hundreds of potassa salts may be prepared. But those only will here be considered which are of especial importance in science, the arts, or the common uses of life.

206. *Sulphate of Potassa* (KO, SO_3).

Fig. 111.

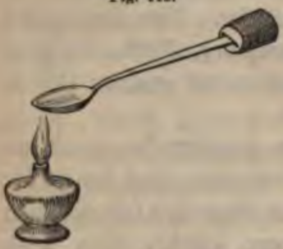


Dissolve half an ounce of potash in two ounces of warm water, and neutralize with diluted sulphuric acid; evaporate the filtered liquid till a film appears on the surface, then let it remain quiet for one day. The hard crystals obtained (six-sided double prisms) are sulphate of potassa; they are sparingly soluble in water, and have a somewhat bitter taste. This salt forms a constituent of the well-known alum.

emits the odor of sulphuret
same time, the iron is bla
sulphuret of iron upon the

Experiment e. — Mix tw

Fig. 113.



w
he
sp
ha
a
tur
be
the
nit
tassa remaining behind may
Nitre is on this account we
metals into metallic oxides.

f. — If nitre be heated wit
acid escapes (§ 159).

g. — Animal substances are
by nitre ; it is therefore used

The manufacture of

substances decay without the presence of lime, or some other strong base, no nitric acid, but only ammonia, will be produced; *consequently, it is the strong base which disposed the nitrogen to combine with the oxygen* (§ 146). After the completion of the putrefaction, add water to extract the soluble matter, and a solution of nitrate of lime is obtained, which is converted by carbonate of potassa into soluble nitrate of potassa, and insoluble carbonate of lime. Nitre-beds, so called, are prepared in this way. We also obtain nitre from the East Indies, where it is spontaneously generated in many limestones containing potassa.

208. *Chlorate of Potassa* (KO, ClO_5).

This salt, as its formula indicates, may be regarded as a brother of nitre; but its disposition, compared with that of the latter, is far more intractable and violent, since chloric acid is much more easily decomposed than nitric acid.

Experiments with Chlorate of Potassa.

Experiment a. — Chlorate of potassa is, by merely heating, very easily resolved into oxygen and chloride of potassium; therefore it is used in the preparation of oxygen, as was described in § 59.

Experiment b. — When thrown on glowing coals, it deflagrates still more briskly than nitre; the oxygen, as it is liberated, occasions a very energetic combustion of the coal. This salt cannot be employed in the preparation of gunpowder, as the rapidity with which it explodes would be too much for the guns; yet, on this very account, it is extremely serviceable in fire-works, especially for producing variegated fires. The *greatest caution* must be observed in pulverizing and mixing it, as it may explode by merely rubbing or pounding it. *When it is to be ground fine, it should always be previous-*

ly moistened with some drops of water; the mixing of it with other substances must always be done with the hand.

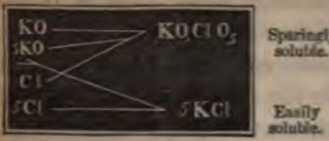
Experiment c.— Introduce some crystals of chlorate of potassa into a beaker-glass, and add a small quantity of alcohol, and afterwards a few drops of sulphuric acid; the sulphuric acid expels the chloric acid, which is immediately decomposed, and there is so great an evolution of heat as to inflame the alcohol.

Experiment d.— Mix some chlorate of potassa between the fingers with about half as much flowers of sulphur, and throw the mixture into sulphuric acid, contained in a beaker-glass; a brisk crackling and an ignition of the sulphur take place. This experiment is daily performed, though in a somewhat different way, in every German household, although not exactly with the view of studying chemistry. Every one performs it who ignites a match by means of the match-flask. The red mass on the end of the match consists of chlorate of potassa and sulphur, which has been colored red by cinnabar; and the flask contains asbestos, moistened with sulphuric acid. The asbestos serves to prevent the too deep immersion of the match.

e.— Chlorate of potassa, like nitre, oxidizes the metals on being heated with them.

f.— If you heat chlorate of potassa with muriatic acid, chlorine escapes. This does not proceed, however, from the chlorate of potassa, but from the muriatic acid, which is deprived of its hydrogen by the oxygen of the chloric acid, in the same manner as it was by the oxygen of the manganese, or of the nitric acid.

Chlorate of potassa is prepared by passing chlorine into a hot solution of potassa; the process is illustrated by the annexed diagram: two salts are formed simultaneously, chloride of potassium and chlorate of potassa; the first is easily, the latter more sparingly soluble in water; they may therefore be separated from each other by crystallization.



Silicate of Potassa is the principal constituent of most rocks and of glass (§ 204).

209. *Chloride of Potassium, or Muriate of Potassa* (KCl).

Dissolve half an ounce of carbonate of potassa in water, and neutralize with muriatic acid; upon concentrating the solution, cubic crystals will be obtained, having a taste similar to common salt. They consist of potassium and chlorine, and if dissolved in water, they may be regarded as muriate of potassa, $KCl + HO$, being the same as KO, HCl.

Fig. 114.

210. *Iodide of Potassium, or Hydriodate of Potassa,* (KI).

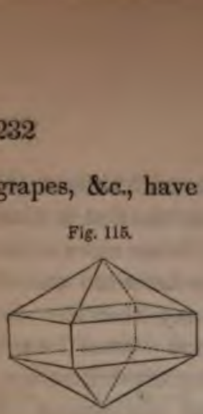
This salt likewise crystallizes in cubes, is easily soluble in water, and is employed in medicine as a valuable remedy.

Experiment. — To prove that iodine is really contained in this white salt, heat a small portion of it in a test-tube with a little manganese and some drops of sulphuric acid, when violet fumes will be evolved. If common salt is treated in the same manner, chlorine, as is known, will be given off. The chemical action is the same in both cases.

211. *Tartar, or Bitartrate, of Potassa* ($KO, 2\overline{T} + HO$).

Common sorrel, the branches of grape-vines, unripe grapes, &c., have an acid taste; they contain an acid salt, tartar (§ 195). These plants absorb the alkali from the soil, but by some unknown process they prepare the tartaric acid by means of their own organization. Ripe grapes also contain tartaric acid, but the sour taste is concealed in them by the sweet taste of sugar, and we do not perceive it until the sugar is converted by fermentation into alcohol; that is, until the must is converted into wine. A great part of the tartar is deposited in the wine-casks as a hard, gray, or red crust (crude tartar). When this is purified from coloring matter by recrystallization, we obtain a white tartar (purified tartar). The powder of it is well known under the name of cream of tartar. Tartar is very sparingly soluble in water. That it burns on heating, forming carbonate of potassa, has been already shown under tartaric acid. *Pure* carbonate of potassa is commonly prepared from tartar.

Fig. 115.



Neutral Tartrate of Potassa ($KO, \overline{T}$).

To prepare this salt, dissolve half an ounce of pure carbonate of potassa in two and a half ounces of water, then add one ounce of purified tartar, and let the mixture stand for a day in a warm place, frequently stirring it. The filtered liquid, after sufficient evaporation, yields prismatic crystals, or, when evaporated to dryness, a white powder. This salt is very easily soluble, but is also very easily decomposed by other acids, even by very feeble ones. On mixing a solution of it with vinegar, a white powder, cream of tartar, is precipitated. The second atom of the base is very easily abstracted by other acids, and thus the sparingly soluble acid salt, *tartar*, is again formed.

As in the above experiment the second atom of the acid in the tartar was neutralized by potassa, so we can also neutralize it by other bases. We obtain in this manner double salts, several of which are used as valuable medicines.

Tartrate of potassa + tartrate of water = cream of tartar.
" " " + " " soda = Rochelle salts.
" " " + " " ammonia = ammoniated tartar.
" " " + " " peroxide of iron = tartarized iron.
" " " + " " oxide of antimony = tartar emetic.

212. *Salt of Sorrel, Acid Oxalate, or Binoxalate of Potassa* ($KO, 2 C_2 O_3 + 2 HO$).

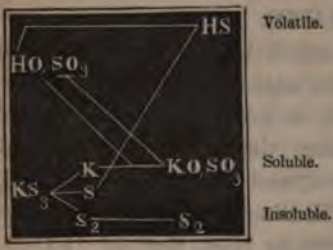
The leaves of the wood-sorrel have a sour taste, and contain also an acid salt, the base of which is likewise potassa; the acid, however, is not tartaric, but oxalic acid. In those places where the sorrel grows abundantly the juice is expressed, and the salt is obtained, by evaporation and crystallization, in white, sparingly soluble crystals. It has already been noticed (§ 197). It is in common use for removing ink-spots from linen.

213. *Liver of Sulphur, or Tersulphuret of Potassium* ($3 KS_3 + KO, SO_3$).

Experiment.—Put a mixture of one drachm of sulphur and two drachms of dry carbonate of potassa into an iron ladle; cover it with a strip of sheet-iron, and heat it until the effervescence has ceased and the mass flows quietly. The fused mass has the color of liver, and on this account has received the name *liver of sulphur;* pour it upon a stone, and if it should inflame, cover it with a vessel to extinguish it. On exposure for some time to the air it becomes greenish and moist, and evolves an odor like that of rotten eggs. The simple sulphur cannot combine directly with the compound carbonate of potassa, but it can do so if the latter surrenders its carbonic acid and its oxygen. This does take place.

The carbonic acid escapes with effervescence, while the oxygen combines with one quarter of the sulphur, forming sulphuric acid, which unites with a portion of the undecomposed potassa, forming sulphate of potassa; accordingly, the liver of sulphur is a mixture of *tersulphuret of potassium* and *sulphate of potassa.*

Experiment. — Pour water into a test-tube containing some liver of sulphur; you obtain a yellowish-green solution. If to this you add diluted sulphuric acid, a strong evolution of *sulphuretted hydrogen* takes place, and the liquid becomes milky from the precipitation of two thirds of the sulphur (milk of sulphur). A decomposition of water hereby takes place; the oxygen of the water converts the potassium into potassa, which unites with the sulphuric acid, but the hydrogen escapes, with one third of the sulphur, as sulphuretted hydrogen. The same thing is effected, though far more slowly, by the carbonic acid of the air, and thus is explained why the liver of sulphur (as well as the residue left on the combustion of gunpowder) emits a smell like that of rotten eggs when it is left exposed to the air.



The liver of sulphur is chiefly used for preparing sulphur baths. A similar preparation is obtained in the moist way, as has been described (§ 129).

Besides this combination of *potassium* with *sulphur*, there are several others, containing either more or less sulphur. The simplest compound of sulphur and potassium (K S) is obtained by heating together sulphate of potassa and charcoal, which latter abstracts the oxygen both from the potassa and from the sulphuric acid, forming with it carbonic oxide, which escapes. In the same manner all sulphates are converted into *sulphurets* by heating them with charcoal.

214. *Potassa Salts as Manure.* — The salts of potassa exercise a very beneficial influence upon the fertility of the soil, and are particularly adapted for those plants, in the ashes of which, when burnt, the potassa salts are found; namely, for the grape-vine, potatoes, turnips, &c. Such plants may be called *potassa plants.* It is now known that plants do not flourish even in the richest soil, unless they find in it certain bases (potassa, lime, &c.), and also certain acids (silicic, phosphoric, sulphuric, &c.). In order to ascertain what acids and bases, or, in other words, what salts, are required for the cultivation of a certain plant, it is merely necessary to burn this plant and examine the ashes. The substances which are found, though their amount is generally but very small, must be regarded as *indispensable to the nourishment of this plant.* If the soil is destitute of potassa, neither turnips nor grape-vines will flourish in it; if destitute of lime, it will produce neither clover nor peas. By the addition of potassa salts we can restore to such a soil its fertility for the potassa plants, and by the addition of lime we again render it productive for the lime plants. On this is founded the application of the so-called *mineral manure* (lime, gypsum, wood-ashes, salt, &c.) to our fields. Common manure also, and soap-suds, operate partly in the same way, since they are rich in phosphoric acid, as well as in alkaline and in lime salts. If turnips are cultivated season after season upon the same field, the potassa will finally become exhausted, and turnips will no longer grow there; the same thing happens when peas are

planted year after year upon the same land, as they will at last exhaust all the soluble lime from the soil. But turnips will flourish in this latter field, because it still contains potassa, and peas in the former field, where lime is still present. Thus is explained, in a very simple manner, the advantage of the *rotation of crops*, which has been universally introduced into agriculture.

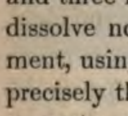
SODIUM (Na).

At. Wt. = 290.—Sp. Gr. = 0.9.

Common Salt, Chloride of Sodium, or Muriate of Soda (Na Cl).

215. *Experiment.*—Dissolve one ounce of salt in two and three fourths ounces of cold water; the water will dissolve no more, even if added. Repeat the experiment, using hot instead of cold water; the result is precisely the same. Common salt has the remarkable property of *being equally soluble in hot and in cold water.* A larger quantity of almost all other salts is dissolved by hot than by cold water. Put one of these solutions in a warm place; by the gradual evaporation, regular transparent crystals of common salt are formed. Boil down the other solution, quickly stirring it all the while; it yields a granular, opaque, saline powder (disturbed crystallization). Salt is prepared as last described on a large scale, and hence the granular state of common salt.

Fig. 116.



Experiment.—If you expose a solution of salt in an open place during the extreme cold of winter, transparent prismatic crystals will be formed, which contain more than one third of water. When placed on the hand they quickly become opaque and deliquesce into a syrupy mass, in which numerous small cubic crystals may be perceived. This experiment shows very clearly, —

1.) How one and the same body may assume different forms at different temperatures; at common temperatures salt crystallizes in anhydrous cubes, but under the influence of cold in hydrated prisms.

2.) How great an influence temperature exerts upon the affinities of bodies for each other. At a temperature above the freezing point, salt has no affinity for water; we obtain anhydrous cubes; below the freezing point it has an affinity for water, and we obtain prisms which consist of a chemical combination of salt and water.

3.) How easily chemical bonds of affinity may be destroyed again; the heat of the hand even is sufficient to destroy the affinity of salt for water.

Experiment. — Heat some common salt on a platinum foil; it will snap briskly, and part of it will be thrown off from the foil; that which remains *melts* when the foil becomes red-hot. The snapping proceeds from a trace of water (water of decrepitation), which has remained in the interstices of the crystals; on being heated it expands and bursts the crystals asunder.

Salt has been previously twice artificially prepared; namely, once from sodium and chlorine (§ 153), and again from soda and muriatic acid (§ 186); its constituents are accordingly already known. It has the formula $Na\,Cl$. If water is present, it may be regarded also as muriate of soda, for $Na\,Cl + H\,O$ is equal to $Na\,O, H\,Cl$.

216. The earth and sea abound in common salt; it may therefore be easily procured in large quantities.

In many places it is found in the interior of the earth, in immense beds, from which it is broken up and dug out. This salt looks like a transparent stone, and so is called *rock-salt.* In those places where the rock-salt is mixed with stones and earth, a hole is bored in the middle of the bed, and water is let into it. The water is pumped out again as soon as it has become saturated with the salt, and is again expelled by evaporation. In some places springs are found containing salt in solution, the so-called *natural salt springs.* These are always occasioned by the water permeating the earth over a bed of rock-salt, and appearing as a spring at some lower level.

As the *natural springs* commonly contain much more water than is necessary for the solution of the salt, a cheaper method than that of fire, namely, a current of air, is first employed for the evaporation of it. The salt water is pumped up to the top of a lofty scaffolding filled up with fagots (*graduation-house*), and from which it is made to fall by drops through the fagots. It diffuses itself over the branches, and thus presents a very large surface to the air passing through, whereby a very rapid evaporation is effected. All natural salt waters contain gypsum in solution; this is first deposited, since it is difficultly soluble, and encases the branches with a hard crust. When the greater portion of the water is evaporated, the concentrated brine is finally boiled down with constant stirring in large pans, and the granular salt, which separates, is raked out and dried. During the evaporation, a solid incrustation is deposited at the bottom of the pans, consisting principally of Glauber salts and gypsum, and from which Glauber salts are extracted. Finally, a somewhat thick liquid remains, the so-called mother-water, from which no more salt can be extracted; it contains the easily soluble foreign salts present in the brine, namely, chlorides of calcium and magnesium, and bromide of magnesium, and is used for baths and for the preparation of bromine.

In hot countries, salt is also prepared from sea-water, which is evaporated in shallow tanks by the heat of the sun. It is called *bay-salt*, and has a bitterish taste, owing to the presence of salts of magnesia. A pound of sea-water contains from one half to five eighths of an ounce of common salt.

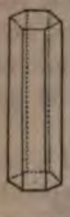
217. Small quantities of common salt are found in almost every spring of water, in every soil, in every plant. Is this universal diffusion of salt to be regarded as accidental? By no means. This is one of the spiritual advantages to be derived from the study of the natural sciences, that they lead us to distinguish, in the wonderful arrangements of nature, not the sport of chance, but the forming hand of an Eternal Wisdom. We find common salt everywhere in nature, because it is indispensable to the life of animals and plants. Without salt, no complete digestion of food could take place, and therefore we justly regard it as a universal condiment. Animals find it in the meat and plants by which they are nourished; plants receive it from the soil and rain, and it is well known that we can promote the fertility of our fields by the application of a coarse kind of salt.

Salt is also used for preserving animal and vegetable substances, it having the power of preventing chemical decompositions, or, in common language, putrefaction or decay. Meat and fish are salted down, and wood for the purpose of building is rendered more durable by being impregnated with salt.

218. *Glauber Salts, or Sulphate of Soda* ($NaO, SO_3 + 10 HO$).

As most of the potassa salts, potassa, and potassium are prepared from carbonate of potassa, so most of the soda salts, soda, and sodium are prepared from common salt. In the latter case, however, an indirect process must often be resorted to, since chlorine is not so easily removed from sodium as carbonic acid is from potassa. The chloride of sodium must first be converted into *sulphate of soda*. We are already acquainted with this salt, it having remained in the retort after the preparation of muriatic acid (§ 185), where common salt was heated with sulphuric acid. It was formerly taken as a popular medicine, under the name of Glauber salts, so called from its discoverer, the physician, *Glauber*. We find it also in many mineral waters, for instance, in the Carlsbad and Pullna waters, and in the incrustation of the salt-pans, as was mentioned under common salt. It is readily soluble, crystallizes in four or six sided prisms, and has a nauseous bitter taste.

Fig. 117.

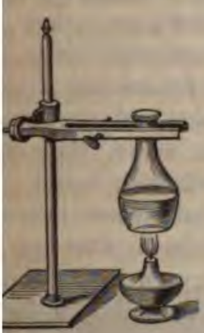


Experiment. — Place half an ounce of transparent crystallized Glauber salts in a warm place; they soon become covered with an opaque white coating, and finally crumble into powder; they *effloresce*. The powder obtained weighs hardly a quarter of an ounce. That which was lost was water. Glauber salts contain more than half their weight of water of crystallization. It is thus obvious that it is this chemically combined water which imparts to the salt its form and transparency, both of which are lost when the water is evaporated by the heat; but they reappear when the pulverulent anhydrous salt is dissolved in boiling water, and the solu-

allowed to cool. Carbonate of potassa is a *deli-*
cent salt, common salt is a *permanent* salt in the air,
e Glauber salts are *efflorescent*. Salts which efflo-
: must be kept in a cool place, well corked up.

xperiment. — If a crystal of Glauber salts is heated
harcoal before the blow-pipe, it soon melts, because
ssolves in its water of crystallization (watery fu-
); it becomes dry as soon as the water is expelled;
finally it melts for the second time when heated to
ess (igneous fusion). Those salts which contain
vater of crystallization undergo only the latter kind
ısion.

Fig. 118.



xperiment. — Heat in a small flask half an ounce of
water to 33° C., and keep it at
this temperature, gradually add-
ing crystallized Glauber salts,
as long as they are dissolved,
amounting to about an ounce
and a half. If a stronger heat
be now applied to the saturated
solution, a salt will separate
(anhydrous crystals); if you let
it cool, a salt will likewise sep-
arate (hydrated crystals); — fur-
nishing another example of the
great influence exerted by tem-
ture on the affinity of water for other substances.
ıber salts have the peculiar property of being most
ble in water, not at the boiling point, but at a lower
berature.

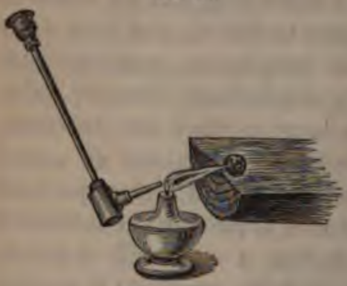
xperiment. — If you dissolve crystallized Glauber
in water, *cold* is produced; but if, on the contrary,
dissolve anhydrous Glauber salts in water, then *heat*
oduced. You will observe exactly the same phe-

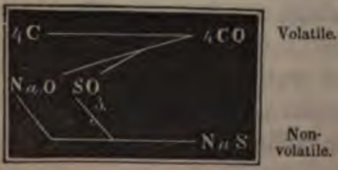
nomena if you perform this experiment with carbonate of soda, taking first the crystallized and then the calcined carbonate of soda. Whence the source of this heat? It comes from the *water*, because a part of the water combines with the anhydrous Glauber salts, or the anhydrous carbonate of soda, as water of crystallization. Consequently, it is a phenomenon very similar to that which takes place in the slaking of lime (§ 33).

219. *Sulphuret of Sodium* (Na S).

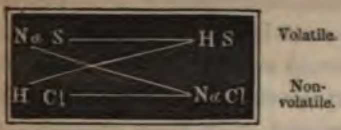
Experiment. — Mix a small portion of anhydrous Glauber salts with a little charcoal powder, and heat the mixture on charcoal before the blow-pipe; they will melt with brisk effervescence into a brown mass, which dissolves in water, forming a yellowish liquid. The coal, when heated to redness, abstracts the oxygen both from the soda and from the sulphuric acid, and forms with it carbonic oxide gas, which escapes with effervescence; sodium and sulphur remain behind, combined with each other. That is, the coal deoxidizes the sulphate of soda, or reduces it to sulphuret of sodium.

Fig. 119.





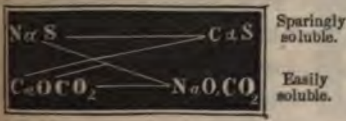
If you drop muriatic or diluted sulphuric acid into



the solution, the disagreeable smell of sulphuretted hydrogen will be given off, just as in the case of liver of sulphur (§ 215). If you now let the liquid evaporate on a glass plate, you obtain, in the former case, small cubes of common salt, and in the latter, a pulverulent incrustation of Glauber salts.

220. *Carbonate of Soda* ($NaO, CO_2 + 10 HO$).

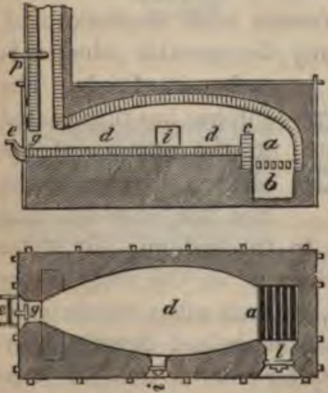
Experiment. — Prepare some more sulphuret of sodium in the manner just described, rub it in a mortar with the adhering particles of charcoal and with about its own weight of chalk, and ignite it again before the blow-pipe. Boil the baked saline mass in water, and then filter the liquid. A gray powder remains behind, which, when drenched with muriatic acid, evolves sulphuretted hydrogen; it is sulphuret of calcium. The liquid, after being evaporated on a shallow glass dish, leaves behind a white powder, which has an alkaline reaction and effervesces with muriatic acid, but yet without emitting any disagreeable odor; it is carbonate of soda. The sulphur has thus passed to the calcium of the chalk, while the oxygen and the carbonic acid of the chalk have passed to the sodium. By these processes it will be seen that, as in the daily affairs of life, so also in chemistry, we can often obtain indirectly that which could not be gained directly. Sodium has a stronger affinity for chlorine than for oxygen; therefore we cannot prepare soda directly from



common salt; but by means of sulphuric acid we can easily convert the haloid salt into an oxy-salt,—into sulphate of soda. The strong sulphuric acid cannot be directly expelled from this; we therefore first decompose it into oxygen and sulphur, and afterwards remove the sulphur by another metal, calcium, which forms with sulphur an insoluble compound. Soda is thus obtained, yet not in a free state, but as carbonate of soda; carbonic acid, however, is so feeble an acid, that it may easily be expelled by another acid, or by caustic lime.

As carbonate of soda possesses almost the same properties as carbonate of potassa, and may be advantageously employed instead of the latter in washing and bleaching, and also in the manufacture of glass and soap, it is now manufactured on a large scale in chemical works. There are, in Germany, laboratories where from ten to twelve thousand quintals of soda are annually made. The process pursued is essentially the same as that already described, except that the two operations, described as separate above, are united into one; the chalk or limestone is added, in the first place, to the Glauber salts and charcoal, and the whole mass is heated. This is done in a large oven-shaped furnace, represented in the figure. *a* is the grate, *b* the ash-pit, *p* the chimney, *d d* the hearth for receiving the mixture, *i* the aperture for throwing in the mixture, and *g* an open-

Fig 120.



ing for stirring it and scooping it out. They are called *flame-furnaces*, because the heating is effected, not by the fuel itself, but by the flame passing over the bridge *c*; they possess this important advantage, that the ashes of the pit-coal or peat do not become mixed with the substance to be heated. In many countries an impure soda is also obtained from the ashes of marine plants (kelp).

Carbonate of soda consists of equal atoms of soda and carbonic acid. It occurs in commerce, either *crystallized*, — it then contains more than half its weight of water of crystallization (10 atoms) and effloresces very very readily, — or *calcined*, consequently anhydrous. The latter, accordingly, when it occurs pure, is of more than twice the strength of the crystallized. Carbonate of soda is easily soluble in water. Many mineral waters — for example, the Carlsbad springs — contain great quantities of it in solution; Carlsbad salt, obtained by evaporating the waters of the spring, is a mixture of carbonate and sulphate of soda.

Bicarbonate of Soda ($NaO, 2CO_2 + HO$)

is more sparingly soluble than the former salt, and is frequently used in effervescing powders, because it evolves on being mixed with acids as much again carbonic acid as the simple carbonate. Effervescing powders are prepared by triturating together equal portions of tartaric acid and bicarbonate of soda. If you put this mixture into water, tartrate of soda is formed, and carbonic acid escapes. When heated, this salt comports itself like the bicarbonate of potassa.

221. *Soda, or Oxide of Sodium* (NaO).

If you take from the carbonate of soda its carbonic acid, soda will remain behind. This is done by boiling a solution of soda with quicklime, in the same manner as was described under potassa (§ 203). The liquid thus obtained is called *caustic soda lye*, and yields, after evaporation, *caustic soda.* This contains, like caustic potassa, yet one atom of water, which it does not part with even when heated to redness; hence it has been more correctly called *hydrate of soda* (NaO, HO). The hydrate of soda has a corrosive action, forms soap with fat, and hard glass when melted with sand; it is a very strong base, like caustic potassa, for which it is often substituted in preference in the arts.

222. *Sodium* (Na).

On abstracting oxygen from the soda metallic sodium is obtained. This metal is prepared like potassium, which it greatly resembles, though it does not act so violently upon other bodies, for instance, upon water. Put upon cold water, it oxidizes without flame, but put upon hot water, the escaping hydrogen ignites, and burns with a yellow flame.

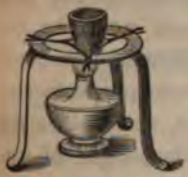
We have now passed from the most widely diffused common salt to the element sodium, treating each one in that succession which it is necessary to pursue in the actual preparation of these substances. The following summary statement may serve to fix them on the memory: — From common salt, or chloride of sodium, sulphate of soda is prepared; from this, sulphuret of sodium; from this, carbonate of soda; then soda; and finally sodium.

A few other *salts* of soda will now be considered.

223. *Phosphate of Soda.*

Experiment. — Neutralize half an ounce of carbonate of soda, dissolved in water, with phosphoric acid prepared from bones; filter the liquid from the phosphate of lime which separates, and evaporate the filtrate until a film forms on the surface; on cooling, transparent crystals will be deposited, which contain more than half their weight of water of crystallization. They easily effloresce, and yield a *yellow* precipitate, with a solution of nitrate of silver.

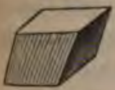
Fig. 121.



Experiment. — Let some of the crystals of the phosphate of soda effloresce in a warm place, and afterwards heat them to redness in a porcelain crucible. When the mass is cold, dissolve it in water, and evaporate the solution; you obtain a salt which contains far less water of crystallization than the former one; it no longer effloresces, and yields with nitrate of silver a *white* precipitate; it has received the name of pyrophosphate of soda. This example shows how the affinity of a salt for water may be weakened by being heated to redness, and how the properties of a salt may be changed, according to the amount of water with which it is chemically united.

224. *Nitrate of Soda* (NaO, NO_5).

Fig. 122.



Experiment. — Dissolve half an ounce of carbonate of soda in a little hot water, and neutralize it with nitric acid; then evaporate the solution till a pellicle begins to form, when crystals will separate, having the form of an oblique rhombic prism; they are nitrate of soda. They deflagrate on charcoal like nitrate of potassa, only somewhat less violently, and have the greatest similarity to it in other respects.

Large districts of this salt are found in America, whence whole ship-loads of it are exported, under the name of *Chili saltpetre;* and it is substituted for the more costly nitre in the manufacture of nitric acid and some of its salts. But it does not answer for making gunpowder, as the powder thus prepared becomes moist, and detonates too slowly.

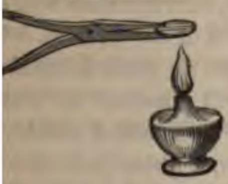
225. *Biborate of Soda* (*Borax*) ($NaO, 2BO_3 + 10HO$).

The hard, colorless crystals commonly called borax, and generally covered with an efflorescent powder, consist of soda and boracic acid. Boracic acid, in the moist condition, is a feeble acid; therefore, like carbonic acid, it cannot entirely conceal the basic properties of soda; and borax has an alkaline taste, and colors red test-paper blue. Borax contains half its weight of water of crystallization.

Experiment. — Heat some powdered borax upon a platinum wire before the blow-pipe; it will puff up and swell in its water of crystallization, and be converted into a porous spongy mass; on being further heated, it fuses to a transparent *bead.* Moisten this bead with the tongue, apply it to litharge so that some of the latter may adhere to it, and again hold it in the exterior flame of the blow-pipe; the litharge is dissolved; the bead remains colorless and transparent. If you now substitute for the litharge other metallic oxides, you will likewise observe that the oxides will dissolve, but that at the same time the bead will be colored by them; namely, *yellowish-red*, by sesquioxide of iron and oxide of antimony; *green*, by the oxides of copper and chromium; *blue*, by oxide of cobalt; *violet*, by a small portion of oxide of manganese; and *brownish-black*, by an excess of manganese. The metallic oxides comport themselves n the same manner, when they are fused into on glass or earthen ware. They are for this rea- alled *vitrifiable pigments* (borates or silicates of ic oxides).

account of this property which borax has of dis- g metallic oxides, it is used in chemistry as a pipe test for the *detection* of metallic oxides, and trades for *soldering*, or joining one metal with er.

Fig. 123.



ld by the forceps a piece of copper, on which is placed a piece of tin and iron wire, over the flame of a spirit-lamp; the tin will indeed melt, but it will not adhere either to the copper or the iron. Repeat the experiment, having previously smeared the copper and the with a paste made of borax-powder and water; sult is now quite different, for the melting tin with both metals, and the wire, when cold, is to be firmly soldered upon the copper. The ation of this different result is simply as fol- Metals only adhere to metals when they have polished surfaces; the clean surface is lost on g the metals, because a layer of oxide is formed them by the oxygen of the air; but the bright sur- s restored again by the borax, which, when it dissolves the oxide formed.

ax occurs native (tincal) in many of the lakes of but it is now prepared also from boracic acid, is obtained from some hot springs in Italy, and tralized by soda.

226. *Glass* (*Silicic Acid combined with Bases*).

As boracic acid forms with soda, when heated, a *vitreous* compound, so silicic acid, which is very analogous to boracic acid, forms likewise a vitreous combination with soda, and also with other bases, as with potassa, lime, oxide of lead, oxide of iron, &c. *Glass*, glazing, enamel, &c., are varieties of this combination.

Experiment. — Melt some carbonate of potassa or soda upon a platinum wire before the blow-pipe, and then add a little finely pulverized sand; upon placing it again in the blow-pipe flame, effervescence will ensue, and afterwards a clear bead will be formed. If the proportion of sand used be *small*, the glass formed (basic silicate of potassa or soda) will dissolve in water on long-continued boiling; it is then called *soluble glass* (§ 204). If *more* sand is taken, a glass (acid silicate of potassa or soda) is obtained which it is very difficult to dissolve in water. To make a glass which shall be entirely insoluble, not only in water but also in acids, beside the potassa and soda, some other earth or metallic base — for instance, lime or litharge — must be added. Common glass is thus manufactured in glass-houses.

The materials which are chiefly employed in the manufacture of glass are, — *a*) quartz, flint, or sand; *b*) carbonate of potassa or wood-ashes; *c*) carbonate of soda or Glauber salts; *d*) lime or chalk; *e*) litharge or minium. These substances, after being pulverized, are mixed together, thrown into earthen pots, and heated in a furnace until the mass is one uniform fluid. In this state it may be moulded like wax, cut and bent, pressed into moulds, and blown, and may accordingly be manufactured into all possible shapes and forms; on g, it becomes hard and brittle. In order to di- in a measure the brittleness, the glass must be very slowly (*annealed*). Glass vessels that are cooled often crack when they are carried from into a cold room; this defect may, to a certain be corrected, by gradually heating the vessels in till it boils, and then allowing it to cool very

coloring and painting glass the vitrifiable pig- as noticed in § 225, are employed. The milk- olor which we observe in the opaque glass of p-screens, and in the enamel of the dial-plate of s, is produced by finely ground bone-earth or f tin, neither of which substances is dissolved by eous mass, but only mixes with it mechanically, ders it opaque, as chalk does water. Glass is by sand and emery, polished by sesquioxide of d tripoli, etched by hydrofluoric acid, and very erforated by the point of a three-cornered file, should be frequently moistened with oil of tur-

two principal kinds of glass are, —

rown or Bohemian glass, consisting of potassa lime, and silica.

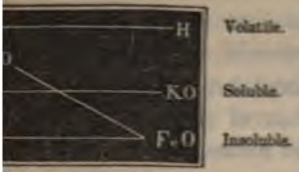
lint or crystal glass, consisting of potassa, oxide and silica.

mon *bottle-glass* contains the same ingredients wn glass, with the addition of sesquioxide of hich imparts to it a brownish-yellow color, or of de of iron, which gives it a green tinge. This contained in the impure materials (yellow sand od-ashes) used in the preparation of the ordinary glass.

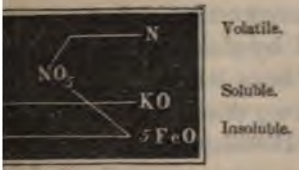
Sulphurets :	Sulphuret of potassium, or Liver of sulphur.	Su
Haloid Salts :	Chloride of potassium.	Ch
	Iodide of potassium.	Iod
Oxy-salts :	Carbonate of potassa.	Ca
	Bicarbonate of potassa.	Bic
	Chlorate of potassa.	
	Nitrate of potassa, or saltpetre.	Nitr p
	Sulphate of potassa.	Sul sa
	Bisulphate of potassa.	Bisu
		Sulp
		Phos
	Silicate of potassa, or glass.	Silic
	Basic silicate of potassa, or soluble glass.	Bibo
	Tartrate of potassa.	
	Bitartrate of potassa, or tartar.	
	Double salts of tartar.	
	Binoxalate of potassa, or salt of sorrel.	
	Acetate of potassa, &c.	

AMMONIA (NH_3).

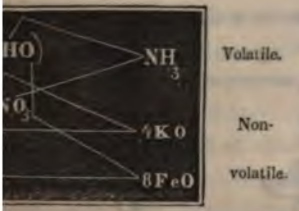
ghted taper; it is *hydrogen.* It comes from the f the hydrate of potassa, the oxygen of which combines with the iron. The potassa serves to hold fast the water, until a red heat is produced: water, by itself, could have been heated only to 100° C.



riment.—2.) Heat forty grains of iron filings and ains of nitre in the same manner as before. You obtain a gas in which a lighted taper is extinguished; it is *nitrogen.* The same occurs in the case of nitric acid as with the water; the iron abstracts from it ; and its second constituent, nitrogen, is thereby , and escapes.



eriment.—3.) Unite the two former experiments into one, that is, heat eighty grains of iron filings at the same time with two grains of potassa and two grains of nitre, in an open test-tube: neither hydrogen nor nitrogen is , but a combination of both in a gaseous form, a pungent odor resembling that of ammonia. of moistened red test-paper held over the test- turned blue; consequently, this new kind of gas es an alkaline *character;* we call it *ammonia.*



In ammonia, one atom of
bined with three atoms of hydr
la is NH_3. From three measu
measure of nitrogen are formed
only two measures, of ammon
the ammoniacal gas occupies o
ously occupied by its constituen
of one half is produced by che
the formation of water from its
densation amounted to two third

228. *Ammonia by dry Distillati*
produced when animal substanc
clusion of air. These substance
gen and hydrogen, which, at the
free by heat, combine with ea
monia.

Experiment.—Reduce to a co

Fig. 124.

of bones, and heat them in a flask as long as any volatile matter continues to escape. The flask must be previously connected, by a bent glass tube, with a bottle containing a little water, which bottle must be kept cool in a basin of water. Adapt to the cork of the receiving bottle another glass tube open at both ends, through which those gases may escape which are not absorbed by the water. These smell very disagreeably, but the odor vanishes when they are inflamed. The gases burn with a luminous flame, like pit-coal gas, which they much resemble in their constitution. A brownish-black *tarry* matter is deposited in the bottle, which is known under the name of oil of hartshorn, or Dippell's animal oil. After the completion of the dry distillation, it is separated from the *watery solution* by filtering through paper previously moistened with water. The filtrate still contains some of this oil in solution, and has thereby a brown color and an agreeable odor. But at the same time we perceive also a pungent smell of *ammonia*, which latter is also detected by means of red test-paper, the color of which is changed to blue.

Add some lime-water to this ammoniacal solution; it becomes turbid, and emits a more powerful odor of ammonia. The turbidness is owing to the precipitation of carbonate of lime, the ammonia not being free in the liquid, but combined with carbonic acid. Carbonic acid is generated during every combustion or charring of organic substances; it here finds a base in the ammonia, and consequently combines with it. In the carbonate of potassa and carbonate of soda, we have already seen that the basic properties of the potassa and of the soda are not entirely concealed by the carbonic acid, — that the base, as it were, still glimmers through. Ammonia also comports itself quite in the same manner; although chemically combined with carbonic acid, it still emits a pungent odor, and affords an alkaline or basic reaction. Formerly this pungent brown liquid was used as a popular sudorific, and was called *spirit of hartshorn*, because it was prepared from harts' horns, instead of from bones. For the same reason, the impure dry *carbonate of ammonia* prepared from it received the name, still in use, of *salt of hartshorn.*

It is only with difficulty that this pungent oil can be separated from the carbonate of ammonia; this separation is most easily effected by converting the carbonate of ammonia into chloride of ammonium.

Sal Ammoniac, or Chloride of Ammonium (NH_3, HCl).

229. *Experiment.* — Neutralize the ammoniacal liquid obtained in the last experiment with muriatic acid; boil it with some animal charcoal, and filter it. After filtration, the liquid has less color than before, because a great part of the coloring matter has been absorbed by the coal (§ 105); after sufficient evaporation it yields brown crystals, which are finally rendered entirely colorless by repeated solution and boiling with coal. This salt was formerly prepared in the district of Ammonia, in Africa, from camel's dung; hence its name, *sal ammoniac.* The ammonia in this, as in its other salts, is so completely neutralized by the acids, that you can no longer recognize it by the smell.

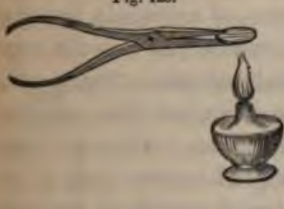
Experiments with Sal Ammoniac.

Experiment a. — If some sal ammoniac is heated upon a platinum foil, over the flame of a spirit-lamp, it volatilizes in white fumes. All ammoniacal salts are volatilized by heat. If the vapor of sal ammoniac is condensed in a cold vessel, you obtain it as a solid, transparent mass, which is pulverized with difficulty. The sal ammoniac of commerce generally occurs in this form; it is then called *sublimed sal ammoniac.*

Experiment b. — Throw some powdered sal ammoniac into water in which a thermometer is immersed; the powder readily dissolves, and the mercury falls considerably. In this manner, *artificial cold* may be produced.

Experiment c. — If sal ammoniac is triturated with slaked lime or potassa, it evolves a strong *ammoniacal odor*, because the potassa or the lime abstracts from it the muriatic acid. This mixture is sometimes used for filling smelling-bottles.

Fig. 125.



Experiment d. — Put a piece of tin, the size of a pea, upon a bright cent, and hold it, by means of a pair of forceps, in the flame of a spirit-lamp; when the tin is melted, rub it upon the cent with a rag; it will not adhere to it. Now repeat the experiment, but strew at the same time some powdered sal ammoniac upon the copper surface; the tin is now equally diffused by the rubbing. On this is founded the important application of sal ammoniac in tinning and soldering. The muriatic acid of the ammonia combines with the oxide of copper formed by heating, and thereby a bright surface of copper is produced, to which the fused tin will firmly adhere; hence we perceive, also, during the process of tinning, a smell of free ammonia. Ammonia and the ammoniacal salts are commonly prepared from sal ammoniac.

Ammonia, or Water of Ammonia $(NH_3 + Aq)$.

230. *Experiment.* — Pour an ounce and a half of water upon a quarter of an ounce of sal ammoniac and three drams of slaked lime, contained in a flask, arranged as described in Fig. 106, and then apply a moderate heat; the lime abstracts from the sal ammoniac, as has already been seen, its muriatic acid, and the ammoniacal gas escapes. As soon as it is released it ascends, since it is nearly one half lighter than common air; it turns red litmus-paper blue, and forms thick white fumes of sal ammoniac when a paper moistened with muriatic acid is held in it. If the longer limb of the tube is now passed nearly to the bottom of a phial containing one ounce of water, the gas is dissolved, and you obtain a solution of ammonia (*water of ammonia*). One measure of water can absorb more than 600 measures of ammoniacal gas. Since much latent heat must therefore be liberated, the receiving vessel should be placed in cold water. A second tube, open at both ends, may be adapted to the cork of the flask to prevent the water being forced back from the phial in case the heat should accidentally be diminished. The tube must reach to the bottom of the flask, for otherwise the gas would escape through it.

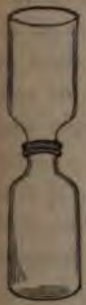
The solution of ammonia is lighter than water, and so much the lighter in proportion to the amount of ammoniacal gas it contains; for this reason, its strength may be very accurately determined by its specific gravity. Its most important properties have already been mentioned. On account of its corrosive properties it is also called *caustic ammonia.*

231. *Hydrosulphuret of Ammonia, or Sulphuret of Ammonium* (NH_3, HS).

Experiment. — Pass a stream of sulphuretted hydrogen gas, evolved as described in § 132, into a solution of ammonia, as long as the solution continues to receive the gas. This solution must be kept in well-closed glass bottles, because it is decomposed on exposure to the air, and becomes yellow. It is one of the most important chemical reagents, as will be shown hereafter.

232. *Carbonate of Ammonia* ($2NH_3$, $3CO_2 + 2HO$).

Fig. 126.



The crude carbonate of ammonia has already been treated of; the pure is prepared from sal ammoniac and chalk, by sublimation.

Experiment. — Introduce a mixture of half an ounce of chalk and a quarter of an ounce of sal ammoniac into a four-ounce flask, having a thin bottom; place it in a sand-bath, and heat it over a spirit-lamp. As soon as pungent vapors are perceived, invert a somewhat larger flask over the former, and the fumes will soon condense into a white saline mass. By double elective affinity there are formed volatile *carbonate of ammonia*, which sublimes, and *chloride of calcium*, which remains behind, since it is not volatile.

Carbonate of ammonia (or, more correctly, sesquicarbonate of ammonia) is a white substance having a pungent ammoniacal odor, which gradually attracts more carbonic acid from the air, and becomes bicarbonate of ammonia. This salt is frequently used by bakers, instead of yeast, for raising gingerbread, spice-cakes, &c.; it escapes in the heat as a gas from the dough, and renders it light and porous.

Other ammoniacal salts may easily be prepared from the carbonate of ammonia, by expelling the carbonic acid by means of a stronger one; for instance, by sulphuric, nitric, or acetic acid, &c.

233. *Ammonia from putrefying Substances.* — One other source of ammonia yet remains to be noticed. It occurs wherever organic substances are undergoing *putrefaction* and *decay*. Carbonate of ammonia is evolved from all vegetable and animal substances which contain nitrogen, when they putrefy or decay; hence the pungent odor of stables and manure-heaps. If you put a bowl containing muriatic acid or diluted sulphuric acid in such places, the odor vanishes, and the muriatic acid is gradually converted into muriate of ammonia, and the sulphuric acid into sulphate of ammonia. Thus we possess in the acids a simple and cheap means of purifying the air in such places. Putrid urine contains so much carbonate of ammonia, that it is used instead of soap-water for washing wool, and indeed even for the preparation of muriate of ammonia itself.

234. When we reflect upon the action of the animal substances already treated of, we cannot but be surprised to find how very much the *nitrogen* contained in them varies in its affinity for other elements.

The nitrogen of organic substances combines, —

With hydrogen, at common temperatures, forming ammonia (decay).

With oxygen, at common temperatures, and in the presence of a strong base, forming nitric acid in nitre-beds.

With hydrogen, on the application of heat and *without* access of air, forming ammonia (dry distillation).

ith carbon, on the application of heat, without ac- of air, and in the presence of a strong anhydrous forming cyanogen.

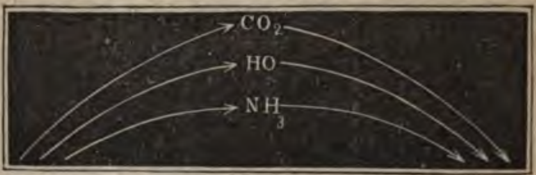
ith hydrogen, on the application of heat, without s of air, and in the presence of a hydrated base, ng ammonia.

t it escapes uncombined, on the application of with free access of air (complete combustion).

5. *The Salts of Ammonia afford an excellent ma- for soils.* They are the principal ingredients in kinds of manure; and therefore we should en- our to prevent the escape of ammonia from manure- s, by sprinkling them from time to time with di- sulphuric acid, or by strewing gypsum over them, eby sulphate of ammonia is formed, which does olatilize at common temperatures. When bones , carbonate of ammonia is likewise produced from elatine, and to this is to be ascribed the second icial influence which pulverized bones exercise the growth of our cultivated plants (§ 176). e plants which grow wild can receive only so ammonia as they find in the air; but by manur- e give a much larger quantity of it to cultivated s; and thus is in part explained the far greater ty of manured arable land in comparison with which is not manured.

nmonia affords another example of the circulation great economy of nature, similar to that present- the instances of carbonic acid and water, the two principal sources of nourishment for the vegetable ; and we cannot but be astonished at the simple er in which the Creator has connected life and with each other. During the processes of putre- n and decay, *the dead* animals and plants are converted into carbonic acid, water, and ammonia; and from these three products of decay are reproduced all the innumerable plants which cover the surface of our earth.

Fig. 127.



236. The great resemblance of ammonia to potassa and soda has long since given rise to the conjecture, that a metal might also be concealed in it, as well as in the potassa and soda. If a body—for instance, cyanogen—which comported itself exactly like a chemical element, like chlorine, could be generated from nitrogen and carbon, so also it was possible that a body might be formed from nitrogen and hydrogen which should comport itself like a metal, like potassium. Chemists have not yet succeeded in separating such a metal from ammonia or its salts; nevertheless, the opinion is maintained by many of them, that such a metal does really exist, and consists of one atom of nitrogen and four atoms of hydrogen (NH_4). They have called it *ammonium*; and, according to this view, regard hydrated ammonia ($NH_3 + HO$) as oxide of ammonium ($NH_4 O$), muriate of ammonia ($NH_3 + HCl$), as chloride of ammonium ($NH_4 Cl$), &c., which amounts to the same thing, since the constitution of these two bodies is not changed, whether the hydrogen is considered as belonging to the water or to the muriatic acid, or as combined with the ammonia.

A compound of one atom of nitrogen and two atoms of hydrogen (NH_2) has been called amide.

LITHIUM.

A very rare base, lithia or oxide of lithium, occurs in several minerals and mineral waters; it possesses properties analogous to those of potassa. Many salts of lithia impart a beautiful crimson color to the blow-pipe flame, and to the flame of burning alcohol.

RETROSPECT OF THE ALKALIES (POTASSA, SODA, AND AMMONIA).

1. Of all bodies, potassium and sodium have the greatest affinity for *oxygen;* they float upon water, and decompose it with great violence.

2. Their oxides are the most powerful *bases*. The oxide of potassium is commonly called potassa, or caustic potassa; the oxide of sodium, soda, or caustic soda; and ammonia may also be regarded as caustic ammonia.

3. These three oxides are commonly called *alkalies*, also caustic alkalies. Formerly potassa was called vegetable alkali; soda, mineral alkali; and ammonia, volatile alkali.

4. The alkalies are *easily soluble* in water, have an *alkaline* taste, and exert a *strong caustic* action on animal and vegetable substances.

5. The alkalies have a very great affinity for *carbonic acid.* They absorb it eagerly from the air, and become converted into alkaline carbonates.

6. Carbonic acid *cannot* be expelled from the alkaline carbonates by heating, but it escapes immediately, with effervescence, on the addition of other acids.

7. The alkaline carbonates, carbonate of potassa, of soda, and of ammonia, are *easily soluble* in water, and have likewise an alkaline taste and a basic reaction.

8. Potassa and soda, with sand, yield melted *glass;* and with fat, a *soap*, which is soluble in water.

9. Most of the salts which the alkalies form with acids are soluble in water. Most of the potassa salts are permanent in the air, some deliquescent; most of the soda salts contain water of crystallization, and effloresce in a dry atmosphere.

10. Potassa and soda salts are not volatile in the heat, but the salts of ammonia are so.

11. A weaker base will often remove the acid from a stronger base, when it forms with this acid an insoluble compound.

SECOND GROUP: THE ALKALINE EARTHS.

CALCIUM (Ca).

At. Wt. = 250. — Sp. Gr. ?

Chalk, or Carbonate of Lime (CaO, CO_2).

237. It is already known that chalk consists of carbonate of lime; it was used, indeed, in several of the earlier experiments for the preparation of carbonic acid. We find just the same constituents also in common limestone, in marble, oyster-shells, &c. There are whole ridges of mountains consisting of limestone, and extensive districts having a lime or calcareous soil; carbonate of lime is one of the principal constituents of our earth. We also find it in transparent crystalline forms, rhombohedrons, and six-sided prisms, and then call it calcareous spar. The great difference which these stones present in their exterior appearance cannot be wondered at, for we see a similar variety of form in our common sugar; we have it crys-

Fig. 128.

tallized in candy, granular-crystalline in loaf-sugar, amorphous in bonbons, and pulverulent in pounded sugar.

All limestones *effervesce* when treated with an acid, and may thus generally be distinguished from other stones. If you smear a piece of limestone in single spots with fat or some varnish-paint, and then pour upon it an acid (a weak solution of nitric acid is the best), the lime dissolves in those places only which are unprotected by the fat or paint, the greasy spots accordingly remaining raised. If a stone thus prepared is passed over with printing-ink, this will adhere only to the elevated places, and may be transferred from them to paper. This is the method used for engraving on stone, and the limestones used in this kind of engraving are called *lithographic stones*.

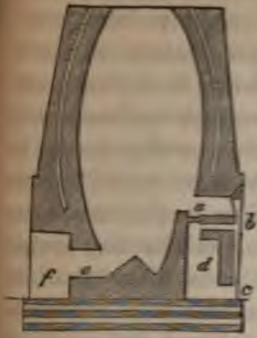
Experiment. — Blow air into lime-water, through a glass tube; a precipitate of carbonate of lime is formed (see Fig. 81); continue the blowing, and the precipitate will, for the most part, dissolve again. The carbonic acid first precipitates the lime, then it dissolves it again. Carbonate of lime is quite insoluble in water, but is soluble in water impregnated with carbonic acid. Let half of the liquid remain exposed to the air, it will gradually become turbid, and carbonate of lime will be deposited; boil the other half in a test-tube, bubbles of carbonic acid will escape, and carbonate of lime will be *rapidly* precipitated. What here happens on a small scale frequently occurs in nature on a large scale. The water, as it trickles through the earth in those places where the decay of organic matter is going on, finds carbonic acid; therefore almost all spring-water contains carbonic acid. The carbonic acid water so formed finds in almost all earths and stones carbonate of lime, some of which it dissolves; therefore almost all spring-water contains carbonate of lime (*hard* water). When this water flows along in brooks, the carbonic acid escapes again, and the carbonate of lime is deposited as sediment; this water, free from lime, is now called *soft* water. The same thing happens when water containing lime, as it percolates through the earth or fissures in rocks, meets with hollows and caverns; here the carbonate of lime frequently deposits itself in solid masses, called *stalactites*. The walls of cellars and bridges are sometimes found covered with an incrustation of *stalactites*. The *calcareous tufa* deposited from the Carlsbad waters also consists principally of carbonate of lime. If you boil hard water, carbonate of lime is also precipitated; this happens especially when large quantities of it are evaporated, as in steam-boilers. Peas and beans, boiled in hard water, become incrusted with a thin coating of lime, which prevents the water from penetrating, so that they do not become soft; for such purposes, the water should previously be boiled, or exposed for some time to the air.

Caustic Lime, or Quicklime (Oxide of Calcium, CaO*).*

238. *Experiment.* — Put a piece of chalk upon coal, and heat it strongly before the blow-pipe for several minutes; it will then become much lighter than before, lose its marking properties, and will no longer effervesce with acids; it has by the heating lost its carbonic acid, and is now called *burnt lime*. If a portion of it is placed on moistened red litmus-paper, it causes blue spots; consequently it has a *basic* reaction, which chalk has not.

For burning large masses of chalk or limestone, kilns of the annexed form are constructed. *a* is the fire-door, with the grate, upon which pit-coal or turf is burnt; *b*, the

Fig. 122.



opening for the draught of air; c and d, the ash-pit. In this, as in the flame-furnace, the flame only enters the kiln, which is filled with limestone; consequently the lime cannot be rendered impure by the ashes of the fuel. A kiln is usually provided with several such furnaces. e and f are the discharge outlets for extracting the lime, when it is well calcined, fresh carbonate of lime being introduced at the top as the burnt lime is removed. Such furnaces may be kept going for years without interruption.

Quicklime has two strong affinities, namely, for *water* and for *carbonic acid.* On exposure to the air it first attracts water, and thereby crumbles into powder, —it is slaked; afterwards it absorbs also carbonic acid, when it again effervesces with acids. The rapid slaking of lime by drenching with water, and the consequent evolution of heat, have been previously treated of (§ 33). Three pounds of lime combine with one pound of water, forming a fine powder of *hydrate of lime* ($CaO + HO$), or slaked lime. When mixed with water into a paste, it is mortar; if more water is added, it becomes milk of lime; and when mixed with 600 times its quantity of water, a clear solution, lime-water, is obtained. Like Glauber salts, it is much more soluble in cold than in hot water, the latter dissolving only half as much as the former. On account of the great affinity of burnt lime for water, it may be employed for drying damp places, and for preparing anhydrous or absolute alcohol from the common alcohol.

Examples of the avidity with which quicklime combines with carbonic acid have already been given, under combustion, and in the preparation of caustic potassa and of caustic soda. Hence it is very useful for purifying air which contains much carbonic acid; for instance, the air in old cellars, wells, mines, or in cellars in which fermenting liquors, as wine, beer, brandy, &c., are kept. Milk of lime is also commonly used for abstracting from crude illuminating gas its carbonic acid, as well as the admixture of sulphuretted hydrogen. It is likewise in general use for whitewashing; it becomes quickly white and dry, and then it is no longer hydrate of lime, but chalk.

239. *Lime as Mortar.* — Glue is used for joining together pieces of wood; and *mortar*, a mixture of lime and sand, for cementing together stones. This is the most important application of lime. A mixture of lime and sand, on exposure to the air, gradually forms into a hard and stony mass. This consolidation is to be ascribed to three causes; — 1st, the water evaporates, and the hydrate of lime remains behind as a cohesive mass; 2d, the lime attracts carbonic acid from the air, and there is formed a mixture of hydrate of lime and carbonate of lime, which possesses greater firmness than either body separately; 3d, on the surface of the sand a chemical combination is gradually formed of the silicic acid with the lime, both becoming, as it were, incorporated together. This explains the remarkable hardness of the mortar in old buildings. When our structures of the present day shall have stood for centuries, the mortar about them will certainly possess the same degree of firmness, provided good quartz sand has been employed in its preparation, and not the argillaceous sand so often used. Sand also diminishes the shrink-

ing or contraction of the mortar, and prevents its cracking as it becomes dry. Old mortar accordingly consists of hydrate of lime, carbonate of lime, silicate of lime, and silica (sand).

If you burn a limestone in which clay is contained, or an intimate mixture of chalk with one fifth of clay, you will obtain a burnt lime, which, when mixed with water and sand, yields a mortar that hardens quickly, like plaster of Paris, and becomes as hard as stone under water; it is called *hydraulic cement*, and is well adapted for building piers of bridges, or other structures under water. Clay is silicate of alumina; therefore hydraulic cement is an intimate mixture of quicklime with silicate of alumina.

240. *Further Experiments with Lime.*

Experiment. — Wrap a piece of quicklime in paper or in a linen rag, and set it aside for some weeks; the paper and the linen will become, after a time, so rotten as to be easily torn; the lime, to use a common expression, has eaten them. Thus quicklime, like potassa or soda, exerts a corrosive action upon organic substances, and for this reason it is also frequently called *caustic lime.* If you rub between the fingers lime made into a paste with water, you readily perceive by the feeling its caustic action upon the skin. In tanneries the hides are immersed in milk of lime, in order to loosen them, so that the hair may easily be rubbed off; and in agriculture, lime is mixed with weeds, such as couch-grass, &c., to accelerate their decomposition. It is, however, altogether wrong to mix lime with manure that is already in a state of decay and putrefaction, because it contains ammoniacal salts, the ammonia of which would be set free by the lime, and escape; the manure would thus lose much of its efficacy.

Many plants, as peas, clover, tobacco, flourish only in a soil containing lime. If you burn such plants, you always obtain, let them grow wherever they will, ashes which contain more than half their weight of lime salts; we call such plants *lime plants*, and must conclude from these two facts, that lime is as indispensable for the life of many plants, as common salt is for that of animals. Thus agriculturalists possess in lime an excellent manure for those fields where lime is deficient.

Experiment. — Dissolve a little soap in hot water, and add lime-water to it; the solution becomes turbid, and afterwards white flakes are deposited, which feel sticky when rubbed between the fingers. The same thing is observed on washing with soap and lime-water; the soap neither lathers nor cleanses. Therefore, water containing lime, the so-called hard water, cannot be used for washing. The viscous mass which separates is lime soap, a combination of the fatty substances contained in the soap with lime. Potassa and soda soap are soluble in water, lime soap is insoluble.

Caustic lime is a combination of oxygen with a metal, which has received the name *calcium* (Ca); it may therefore be called, also, oxide of calcium (Ca O). Lime is, next to the alkalies, one of the strongest bases.

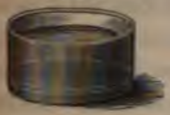
Gypsum, or Sulphate of Lime ($CaO, SO_3 + 2HO$).

241. *Experiment.* — Expose to a moderate heat in an iron vessel the gypsum obtained in former experiments (§§ 164, 176), stirring it during the heating, which must be continued till vapors cease to escape from it; it will afterwards weigh one fifth less than before, and is called *calcined gypsum*. The loss of weight is owing to the

water of crystallization which was driven off by the heat. A temperature of 120° C. is sufficient to effect this.

Experiment. — Wind round the brim of a dollar-piece a strip of paper, firmly securing the loose end of it by sealing-wax. A box is thus made, the bottom of which is formed by the dollar. Now mix two even spoonfuls of calcined gypsum and a spoonful of water into a paste, stir it round quickly, and pour the paste into the box; after a few minutes it will become so hard, that both the paper and the coin can be removed. A reversed impression of the coin will appear on the under side of the gypsum. After this is perfectly dry, smear the impression with a strong solution of soap, mixed with a few drops of oil, and upon pouring over it some of the gypsum paste, a true stamp of the coin will be obtained. The rapid hardening may be thus explained; the anhydrous burnt gypsum again chemically combines with as much water as it has lost during the ignition. If the gypsum had been heated above 160° C., it would not have hardened; it having then lost its affinity for water. In a similar manner, figures of plaster of Paris are made in hollow moulds. Gypsum is used in architecture for making on walls and ceilings various ornamental figures and designs, called stucco-work.

Fig. 130.



Gypsum is a mineral of very frequent occurrence in nature, and in some localities, as at Jena, it forms entire ranges of hills. When crystallized in tables it is termed *selenite*, and the white, compact, granular variety is called *alabaster*. It is also frequently contained in spring-water.

Gypsum is very sparingly *soluble* in water, half an ounce of the latter dissolving only half a grain of gypsum.

To detect gypsum in a liquid, add to one portion a solution of chloride of barium, whereby the presence of sulphuric acid is indicated; and to another portion, a solution of oxalic acid, by which the presence of lime is shown. Oxalic acid is the most certain test for lime salts (§ 197).

That gypsum, as well as quicklime, is a valuable manure for many plants, especially for the leguminous plants, is well known to farmers, who frequently spread it over their clover-fields. The plants hereby not only absorb the lime, but also the sulphur of the sulphuric acid. Gypsum has also a beneficial effect on the growth of plants, as it absorbs the carbonate of ammonia contained in the air and in rain-water, and fixes it in the soil, these two salts being converted respectively into sulphate of ammonia and carbonate of lime.

When gypsum is heated to redness with charcoal, *sulphuret of calcium* is obtained, which, like the liver of sulphur, evolves sulphuretted hydrogen, when drenched with diluted acid.

242. *Phosphate of lime* constitutes, as already mentioned, the principal ingredient of *bones;* it occurs in the mineral kingdom as apatite and phosphorite.

243. *Nitrate of lime* ($Ca\,O, N\,O_5$) is always formed when azotized substances and lime remain for some time together in contact (§ 207). This salt is very often generated in the plaster of walls, in those buildings where urinous liquids or ammoniacal fumes are present, as in stables. The lime loses hereby its adhesiveness, and crumbles, especially when the rain washes out the easily soluble nitrate of lime. This process is commonly called the crumbling away of the walls.*

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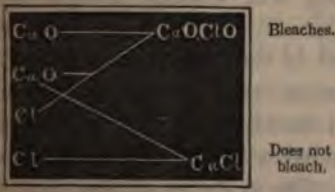
* "The injury thus done to a building by the formation of soluble nitrates has received (in Germany) a special name, *Saltpetrefrass* (production of soluble nitrate of lime)." — Liebig's *Ag. Chem.*

Chloride of Lime, or Hypochlorite of Lime ($CaO, ClO + CaCl$).

244. *Experiment.* — Mix half an ounce of slaked lime with six ounces of water, and conduct into this milk of lime, with frequent agitation, as much chlorine as will evolve from two ounces of muriatic acid and half an ounce of black oxide of manganese. The liquid, clarified by standing, may be regarded as a solution of *chloride of lime*, and must be kept protected from the air and light. It would seem at first as if the chlorine united directly with the lime, but this is not possible, since, as a general rule, simple bodies cannot combine with compound bodies. The process is as follows. Half of the lime releases its oxygen, and is converted into calcium, which, being a simple body, combines with chlorine; the oxygen, liberated from the lime, combines with the rest of the chlorine, forming hypochlorous acid (ClO), which, being a compound body, can now unite with the other half of the lime. Thus are formed a haloid salt, chloride of calcium, and an oxygen salt, *hypochlorite of lime.* The latter is the essential agent, the bleaching power, in the chloride of lime; chloride of calcium is to be regarded only as an unnecessary make-weight. Accordingly the name of chloride of lime is incorrect, but, like many other terms of general acceptation, it would be inconvenient not to retain it. It must not be forgotten, however, that *chloride of lime* is a very different body from *chloride of calcium.*



By the old process, bleaching required weeks, and even months; now, by means of chloride of lime, cotton and linen are bleached in as many days. For this reason, vast quantities of chloride of lime are manufactured in chemical laboratories, and are consumed in bleacheries and calico print-works. The preparation of it on a large scale is conducted upon the same principle as that just described, except that, instead of milk of lime, slaked lime is used, which is spread upon hurdles in chambers, and which, like milk of lime, absorbs the chlorine. Chloride of lime, thus prepared, is a granular powder, which absorbs moisture from the air, and emits the odor of chlorine. Upon adding water to it, the same liquid is obtained as that prepared above.

245. *Experiments with Chlorine.*

Experiment a. — Immerse a piece of cotton, printed with various colors, into a solution of chloride of lime; if there are vegetable colors among those with which the cotton is printed, they will bleach, though but *slowly*.

Experiment b. — Proceed in the same manner, adding, however, to the solution some drops of diluted muriatic or sulphuric acid; the bleaching will then take place *instantaneously*, attended with the evolution of a strong smell of chlorine. The acids expel the feeble, hypochlorous acid, and this is resolved into oxygen and chlorine. If you let the material remain for some time in the solution of the chloride of lime, the vegetable fibres will also be decomposed (*eaten*) by the chlorine, and will lose their firmness.

Experiment c. — Drop some tincture of indigo into a portion of the solution; the indigo is immediately decomposed, and its blue color changed to yellow. Continue to add the indigo till the blue color remains unaffected, and note the quantity of indigo used; in this manner the strength of the different sorts of chloride of lime may be determined, for the more hypochlorous acid there is contained in the chloride of lime, so much the more indigo it is able to deprive of its color.

Experiment d. — Chloride of lime, as well as free chlorine, destroys the *noxious effluvia* evolved during the decay or putrefaction of organic substances. The impure air of stables is destroyed by strewing about chloride of lime, and damp cellars are purified by washing the floors and walls with a solution of it, &c.

In all these decompositions, the chlorine always combines with the *hydrogen* of the coloring and odorous matter.

If chlorine is conducted into a solution of carbonate of soda, instead of into milk of lime, we obtain *hypochlorite of soda*, likewise a bleaching liquid, known as *Labarraque's disinfecting liquor.*

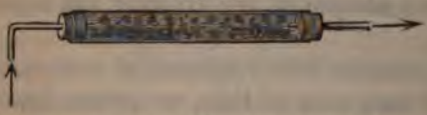
Chloride of Calcium, or Muriate of Lime ($Ca\,Cl$, or $Ca\,O, H\,Cl$).

246. *Experiment.* — Mix muriatic acid with half its quantity of water, and add to it pieces of chalk until effervescence ceases; then evaporate the filtered solution to the consistency of a syrup. We obtain from this, on cooling, large prismatic crystals of chloride of calcium, which must be quickly dried by pressure between folds of blotting-paper, and kept carefully excluded from the air, as they are exceedingly deliquescent. In the winter season, this salt may be employed for freezing mercury. For this purpose let it remain one night in a cold place, then grind it up in a cold mortar, and mix it with snow; if some mercury, contained in a glass tube, is now introduced into the mixture, it will become solid, and a spirit-of-wine thermometer will indicate a

temperature of —40° C. The snow and the chloride of calcium melt; from two solid bodies is thus formed a liquid, and during this transition a great quantity of free heat must necessarily become latent.

Crystals of chloride of calcium contain half their weight of water of crystallization; on being heated, the water passes off, and we obtain *fused chloride of calcium*, one of the *most hygroscopic* salts, which may be employed for preparing absolute from common alcohol, and for drying certain gases. For this latter purpose, fill a capacious glass tube with fragments of it, and adapt to each end of the tube, by means of perforated corks, two small glass tubes, through which the gas may be transmitted; during its passage, all the moisture will be abstracted from it by the chloride of calcium. In the preparation of ammonia (§ 230), chloride of calcium is obtained as a secondary product. It has already been mentioned (§ 244), that it forms a constituent (though a useless one) of chloride of lime.

Fig. 131.



247. *Fluoride of Calcium* (Ca Fl), commonly called *fluor-spar*, is a mineral of frequent occurrence in nature, and is often found in cubic crystals of great beauty. It is easily fused by heat (hence its name), and it yields, when treated with sulphuric acid, hydrofluoric acid (§ 190).

BARIUM AND STRONTIUM (Ba and Sr).

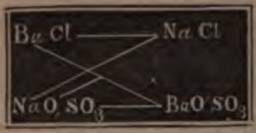
At. Wt. = 855.—At. Wt. = 548.

248. These two metals have so great a similarity to calcium in their properties and combinations, that they may be regarded as brethren. Their oxides are termed baryta (Ba O) and strontia (Sr O), and when water is added to them they evolve heat, as is the case with lime, and afford a *basic* reaction. The carbonates of baryta and strontia are, like chalk, *insoluble* in water, and at a strong heat lose their carbonic acid, yet not so readily as chalk. The salts of lime, as has been seen, are very easily prepared by merely adding acids to marble or chalk; but the salts of baryta and strontia are not so easily obtained, because baryta and strontia are rarely found in nature combined with carbonic, but most frequently with sulphuric acid; consequently, with an acid which is stronger than all others. It is therefore necessary, as in the preparation of soda, to adopt a circuitous method; it must first be reduced to a sulphuret by heating with charcoal; this sulphuret may be afterwards decomposed by acids.

Chloride of barium, or muriate of baryta (Ba Cl), is the most common soluble salt of baryta. It crystallizes in transparent tables, and is used in medicine. The chemist also makes use of it as the surest test for sulphuric acid and the sulphates (§ 171). Nitrate of baryta serves also for the same purpose.

Sulphate of Baryta ($Ba O, S O_3$).

Experiment. — Dissolve some Glauber salts in water, and add a solution of chloride of barium, as long as any precipitate is produced; chloride of sodium and



Soluble.

Insoluble.

sulphate of baryta are formed by double elective affinity; the latter is quite insoluble in water, and also in acids, and is therefore thrown down as a heavy white powder. The ponderous mineral, known as *heavy spar*, which is frequently found in beautiful tabular crystals, associated particularly with metallic ores, is the native sulphate of baryta. Baryta and the baryta salts are prepared from it. This mineral, when ground to powder, is frequently used for the adulteration of white lead.

The most remarkable characteristic of the *strontia salts* is that of communicating a *crimson tint* to the flame of burning substances. *Nitrate of strontia*, like the other nitrates, deflagrates upon burning charcoal, and is used for producing a crimson flame in fireworks, prepared from potassa, sulphur, and charcoal. *Chloride of strontium*, or muriate of strontia, is soluble in alcohol, and imparts to its flame a crimson color.

MAGNESIUM (Mg).

At. Wt. = 158.—Sp. Gr. = 1.7.

Epsom Salt, or Sulphate of Magnesia ($MgO, SO_3 + 7HO$).

249. Envelop in a fold of strong paper a fragment of serpentine mineral; crush it with a hammer, then pulverize it in an iron mortar, and mix half an ounce of it in a porcelain basin with some common sulphuric acid to the consistency of a paste, and set it aside for some days in a warm place. Then stir in carefully an ounce and a half of water, let the mixture stand again for some days, and finally decant the warm clear liquid.

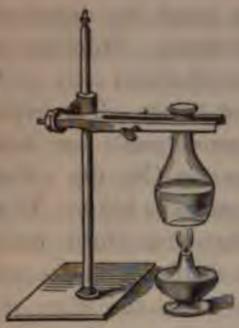
have a green tint, owing to the presence of some
le of iron. When boiling, add gradually nitric
it, until the liquid has assumed a yellow color;
toxide will be thereby converted into sesqui-
f iron. If evaporated until a pellicle is formed,
will be deposited, which must be dissolved
ı boiling water, and recrystallized. Sulphate of
ide of iron, which can be crystallized only with
y, will remain in the mother liquor. The crys-
e a bitter taste. Their constituents are sul-
cid and a base, called magnesia (Mg O). The
all the soluble salts of magnesia is bitter. This
combined in the serpentine with silicic acid,
he stronger sulphuric acid displaces and com-
ith, forming a soluble salt, while the silica re-
ehind undissolved. We find silicate of magne-
in other minerals; for instance, in meerschaum,
ne, talc, asbestos, hornblende, and in several
resembling mica, &c. All these minerals
slippery or greasy feeling, and are mostly in-
nder the general head of talc. Magnesia is
es called also *talc earth*.

n salt is one of the most common purgatives,
nuch employed in medicine. We usually ob-
n commerce, not in perfect crystals, but in the
small acicular crystals, owing to the evaporation
been carried on after the formation of the pel-
d to the stirring of the mass while cooling.
ently a disturbed crystallization has taken
In many places, for instance, at Saidschütz in
a, there are springs holding Epsom salt in so-
nd they are often resorted to by invalids. If
ters are evaporated, this salt is likewise ob-
om them.

Carbonate of Magnesia.

250. *Experiment.*—Dissolve half an ounce of Epsom salt in four ounces of cold water, and add a solution of carbonate of soda as long as a precipitate continues to fall. The precipitate is *carbonate of magnesia*, but sulphate of soda remains in the solution; thus the Epsom salt and carbonate of soda have exchanged their acids. The milky liquid is now heated to boiling, filtered, and the precipitate washed and dried; it is very light and white, and is known as the *magnesia alba* of the apothecaries' shops. During the ebullition, some carbonic acid escapes. Carbonate of magnesia is also found in many kinds of marble and limestone, called *dolomite.*

Fig. 132.



Magnesia (*Oxide of Magnesia*) ($Mg\,O$).

If you heat carbonate of magnesia to redness, it loses, like chalk, its carbonic acid, and at the same time the water with which it was chemically combined; the magnesia remains behind as a light powder, commonly called *calcined magnesia* (oxide of magnesia). It is nearly insoluble in water, and consists of a metal, *magnesium*, and of oxygen.

Chloride of Magnesium, or Muriate of Magnesia ($Mg\,Cl$, or $Mg\,O, H\,Cl$).

251. *Experiment.*—Add to carbonate of magnesia some diluted muriatic acid; the carbonic acid escapes,

ut the chloride of magnesium is dissolved in the quid. This salt is always found associated with com-ion salt, and as it is very soluble and hygroscopic, it emains in the mother liquor on the evaporation of alt-springs. Therefore Epsom salt may also be ob-ained from the mother liquor, by converting chloride f magnesium into sulphate of magnesia. The bitter aste of sea-water is owing to this salt.

Experiment. — Put into a glass of water a few drops f the above solution, or a little Epsom salt, and then dd to it a solution of phosphate of soda ana some mmonia; the liquid first becomes turbid, and finally a rystalline precipitate is deposited (phosphate of mag-esia and ammonia). In this way the presence of agnesia may be most certainly detected.

RETROSPECT OF THE ALKALINE EARTHS (LIME, BARYTA, STRONTIA, AND MAGNESIA).

1. *The metals of the alkaline earths* have, like the lkali-metals, a very great affinity for oxygen; the eparation of them is exceedingly difficult.

2. Their oxides are called *alkaline earths;* — earths, ecause they are sparingly soluble; alkaline, because ey have a basic reaction. (The alkalies are easily luble.)

3. The alkaline earths are, next to the alkalies, the *rongest bases.*

4. The alkaline earths have a *caustic* action, but far ss than the alkalies; hence the terms *caustic lime* and *austic baryta.*

5. They likewise eagerly absorb *carbonic acid* from he air.

6. The carbonates of the alkaline earths are quite

insoluble in water (the carbonates of the alkalies are easily soluble).

7. The carbonates of the alkaline earths *lose their carbonic acid by exposure to a powerful heat* (the alkalies do not).

8. The alkaline earths form with fats *insoluble soap* (the alkalies soluble soap).

THIRD GROUP: METALS OF THE EARTHS.

ALUMINUM (Al).

At. Wt. = 171. — Sp. Gr. ?.

Clay and Loam.

252. The peculiar action of clay on being mixed with water is familiar to every one, forming with it a compact, ductile mass, which may be kneaded into any shape; it is *plastic* or flexible. If a mixture of lime and sand is treated in the same manner, it will not cohere, but remain friable. Common clay contains more sand than plastic clay, and, owing to the presence of iron ochre, has a yellow or brown color. There is still a coarser variety of clay, mixed with still more sand, commonly called loam.

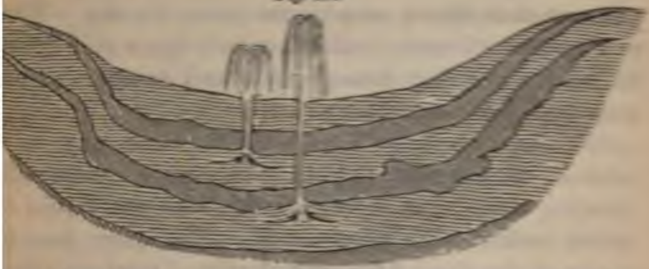
Experiment. — Hollow out a piece of clay, and pour some water into the cavity thus formed; the water will *not percolate* through the clay, as it would through sand or lime. When beds of clay exist beneath the soil, the rain is unable to penetrate far down in those places; and consequently *bogs* and *marshes* are formed. These

Fig. 133.

 be drained by boring holes through the clay-beds, rn to a looser layer of earth, through which the ter can flow off.

There are found in many places in the interior of the th alternate beds of clay and silica, or sand, one

Fig. 134.



ove the other. If these strata ascend on each side, rming hills, the rain-water, as it runs down, must col- t between the layers of clay, and rise in them as in a be, since it cannot find a vent in any direction. If, such a geological formation, a low situation be se- ted for boring through the upper strata of clay, the ter will be forced out above the surface of the soil, d a natural fountain will be the consequence, from ich the water will be forced still higher on boring ough the second layer of clay. These fountains are led *Artesian wells*, from the province of Artois, in ance, where the nature of the soil is peculiarly adapt- to such works.

Experiment. — Put on a paper filter half an ounce dry pulverized clay, and on another half an ounce sand; pour water over each, and weigh them as soon the filtration has ceased; the clay will weigh three hths of an ounce, and the sand only one eighth of ounce more than before. If the sand had been very

you put both filters in a warm p
two species of earths exhibit, wh
difference: the clay forms solid, h
remains a loose, granular powder.

253. *Experiment.* — If you dige
infusion of logwood (§ 174), the
standing some hours, a violet color,
comes much more transparent.
power of *absorbing coloring matter*,
soluble. Potters' clay, or pipe-clay
the same manner towards unctu
hence it is much used for extractin
wood, paper, &c., by spreading it
and letting it remain one or mo
with them. A soft variety of cl
cotton-factories, under the name c
removing again the grease applied
ning.

254. *Experiment.* — Expose half
oughly dried clay to the air for so

lor of ammonia, or only a very slight odor, on being eated in the same manner. Thus is explained, also, e peculiar smell which you perceive in all argillaceous ones when you breathe upon them, and by which you an readily determine whether clay is contained in an arth or stone. As water, carbonic acid, and ammonia re the most important means of nourishment for lants, it is very obvious that clay must enhance the rtility of the soil, because it attracts those substances om the air. That clay is especially efficacious which as remained for years in contact with the air, since in onsequence of slow weathering, soluble salts of lime nd potassa (nitre, &c.) have formed in it.

For this reason, bricks, or clay fragments of old buildngs, are valued by the experienced farmer as excellent manure. Clay, when gently burnt, also experiences a similar change (§ 258).

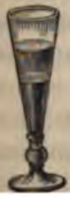
Constituents of Arable Land.

255. *Clay, or loam, and sand form the principal ingrelients of our arable land;* therefore, the knowledge of heir properties is of great importance to the agriculuralist, since it enables him to form a judgment as to he different action of soils in wet or dry, in cold or ot weather, &c. A soil wholly composed either of and or of clay is totally unproductive; but a mixture f them affords a fertile soil. A clayey or *fat* soil is too ompact and heavy, not allowing the roots, of the maller plants particularly, sufficient room to spread; is likewise so dense that it will not allow of a free irculation of air. By showers of short duration it ecomes *baked;* that is, a crust forms on the surface, hich prevents the water from penetrating into the oil; but after long continued rains it becomes *muddy*,

mits the rain to penetrate too de
evaporate again too rapidly. T
tute what is called the physical
the soil. It is now evident, that
of a clayey soil may be amelior
sand, and that of a sandy soil b
loam, or marl.

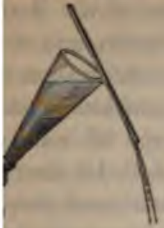
256. *Estimation of Arable Soi*
ascertain the relative amount of
triturate half an ounce of it in
water into a uniform paste. Dil
and pour the turbid liquid into
with water what remains in th

Fig. 135.



ing, the earthy particle
tom, according to their
ities, first the coarse, t
finally the clay or loam
tive conclusion of the c
each may be arrived at
ferent heights of the la
This estimation

Fig. 136.



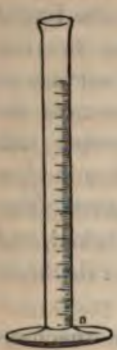
ing, hold a rod against the rim of the glass, so that the liquid may not be lost by flowing down on the outer surface of the vessel, or else besmear the rim with tallow, which will likewise prevent the adhesion of the liquid to the glass. The sand is dried and weighed, and in the original half-ounce is to be calculated

operation, by which light bodies are mechan-
parated from heavier ones, is called *elutriation*.
uently employed to separate finely crushed ores
admixture of the lighter particles of stone and

hird very important ingredient of arable soil is
37), which may be estimated in the following

iment.— Put into a capacious flask half an ounce
lried earth; pour over it three ounces of water,
add gradually half an ounce of muriatic acid,
it remain for some hours in a warm place.
the effervescence has ceased, pour the liquid
ilter, and wash the flask and filter with some
f warm water. Add ammonia to the yellow-
te till it has a decided smell of it; the brown
ecipitate which is hereby separated consists
ted oxide of iron, which you must remove by a
iltration. The clear solution obtained is then
a flask, and a concentrated solution of carbo-
ammonia or carbonate of potassa is added, as
any precipitate forms. This is carbonate of
ich you must collect on a filter, wash, dry,

Fig. 137.



and weigh. A more simple method is to pour the contents of the flask into a graduated glass cylinder, and determine by measure the lime which soon settles at the bottom. You previously determine the weight of a degree of lime, once for all, by dissolving 4, 6, 8, 10, &c., grains of chalk in diluted muriatic acid, precipitating them by carbonate of ammonia, and then marking the space occupied by the precipitate in the graduated cylinder. If you have more liquid than the cylinder holds, you may either evaporate the liquid, or perform the experiment with half the quantity. This method, however, will not give very accurate results when the soil contains not only lime, but also alumina, since this is partially precipitated at the same time with the carbonate of lime.

These two simple tests, the mechanical and the chemical, deserve to be more frequently employed by the farmer than they actually are; indeed, by means of them, and without any costly apparatus or much expense of time, he can make himself sufficiently acquainted with the most important constituents of his different soils.

Earthen-Ware.

257. The *plastic* property of clay, together with that of *hardening* by heat, renders it peculiarly adapted for the manufacture of *earthen-ware*. The clay, having been more or less purified by elutriation and kneading, is either fashioned by the hand upon the potter's lathe, or formed by pressure in moulds into articles of various shapes; these are first dried in the air, and then baked

aces, until they have become hard like stone. ‹y contracts in drying, but still more in baking; ıently, earthen-ware is smaller after being baked ·fore. On account of this property, small cylin- f clay were formerly used for measuring high atures (*Wedgewood's* pyrometer). Though ı-ware acquires by baking great hardness and , yet it still remains so porous as to imbibe and also to let it sweat through. This fault is ed by covering the ware with a vitreous coating, called *glazing*, which is composed of the same ıls as glass (§ 226). The most important kinds ery are,—

Bricks and flower-pots, made of loam or coarse ıostly unglazed. The brownish-red color of the is owing to the presence of oxide of iron.

Earthen-ware, made of common clay, and coated glazing of litharge and clay.

Stone-ware (fine earthen-ware), made of very clay, and likewise covered with a glazing of li- and clay.

Delft-ware, stone-ware covered with a glazing, is rendered opaque and of a milky whiteness el) by oxide of tin (white Dutch tiles, &c.).

Porcelain is made of the finest clay (porcelain kaolin), with felspar, and baked till fusion com- s; the glazing consists of potassa-glass, without e.

English stone-ware (ordinary porcelain) is made clay, not strongly baked; the glazing is prepared ommon salt, which is thrown into a hot pottery e, and consists of soda-glass without litharge pans, beer-flagons, &c.).

y the vitrifiable pigments (metallic oxides) can

be employed for staining and ornamenting the differ
kinds of pottery.

Composition of Clay.

258. *Experiment.* — Dry thoroughly a piece of wh
clay, and expose it for some hours to a powerful h
which is most easily done on the hearth of a hea
oven; then rub two ounces of it to a powder in a p
celain bowl with one ounce of sulphuric acid; p
upon the mixture one ounce of water, and let it rem
some weeks in a warm place. Frequently stir
mass during this time with a glass rod. Finally, dil
it with six ounces of boiling water, and strain it throu
linen. The residue on the latter consists principally
silicic acid, but a base called *alumina* ($Al_2 O_3$) is fou
dissolved in the liquid.

Clay is, accordingly, an insoluble salt, *silicate*
alumina. Before the clay is heated, the silicic a
holds on so firmly to the base that the sulphuric acid
not able to expel it; but it can do this after the c
has been moderately heated. All clay (and loa
contains, besides silicate of alumina, variable quantit
of silicates of potassa, soda, lime, &c., which
likewise rendered dissolvable by burning the clay.
these alkalies, as well as to the greater porosity of
heated clay, it is to be attributed that a heavy clay
soil, which is impervious to the air, is converted mer
by burning into very fertile arable land, and that bad
(slightly) burnt bricks yield a very efficient material
manure.

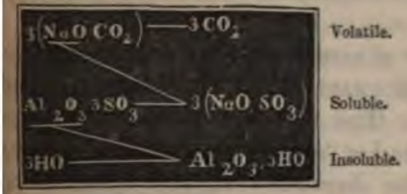
Sulphate of Alumina ($Al_2 O_3, 3 SO_3 + 18 HO$).

259. *Experiment.* — Evaporate the liquid obtained i
the former experiment till only one and a half or tw

nces of it remain, and then put it in a cool place; will crystallize in thin silky plates of a pearly lustre, hich are very deliquescent; it is *sulphate of alumina.* our off the liquor remaining behind, which always ontains free sulphuric acid, and again dissolve the rystals in a little water. In factories the solution is requently evaporated to dryness, and a solid mass is hereby obtained, which is employed in calico-printing nd dyeing.

Alumina, or Oxide of Aluminum ($Al_2 O_3$).

260. *Experiment.* — Add a solution of carbonate of oda to half of the above solution of sulphate of alumina, until the liquid reacts basically; a brisk effervescence ensues, and a gelatinous precipitate is formed, which, after repeated washings with water, will dry in a warm place into a white powder. This powder is a combination of alumina with water, *hydrate of alumina* ($Al_2 O_3, 3 H O$). It is insoluble in water, and cannot combine, like the bases previously considered, with carbonic acid; hence the carbonic acid gas, set free from the carbonate of soda, escapes with effervescence. Alumina differs from clay in *not being rendered plastic* by water, and from lime, baryta, strontia, and magnesia in *not giving* an alkaline reaction.



The constituents of alumina are aluminum and oxygen, consisting of one atom of aluminum and one and half of oxygen. Such bases are called sesquibases to istinguish them from the simple bases, hitherto considered, as $K O$, $Na O$, $Ca O$, &c. The numbers of these sesquibases are doubled, in order to avoid the inconvenience of using fractions; thus $1:1\frac{1}{2}::2:3, = Al_2 O_3$.

Experiment. — Heat in a test-tube some alumina with potassa; it dissolves in it *completely*, since it enters into combination with the potassa. We call alumina a *base*, because it combines with acids; we may also regard it as an *acid*, for it combines also with bases. We shall hereafter find among the metallic oxides other such irresolute, double-faced characters, which play the part of a base towards strong acids, and of an acid towards strong bases. Striving to be both, they are in reality neither, and therefore salts with an alumina base always have an acid reaction, and those with an alumina acid a basic reaction, but both of them are very easily decomposed.

Alumina is a body of extremely *difficult fusibility;* we can only melt small quantities of it before the oxyhydrogen blow-pipe. The melted alumina has the appearance of glass, and a hardness which is only surpassed by that of the diamond (artificial rubies). In this form we find alumina also in nature; the *ruby*, the most costly red precious stone, and the *sapphire*, the most costly blue stone, consist of crystallized alumina. *Emery* has also the same constitution, and is employed, on account of its hardness, for polishing metals and glass.

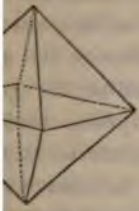
Alum (Sulphate of Alumina and Potassa).
$(KO, SO_3 + Al_2 O_3, 3 S O_3 + 24 H O.)$

261. *Experiment.* — Saturate two ounces of boiling water with sulphate of potassa, and add to it a solution of sulphate of alumina, obtained at § 259. Stir the mixture till it is cold, and decant the clear liquor from the

diment. The sediment is *alum* in a state of
If dissolved in boiling water and *slowly*
you obtain from it crystallized alum in beauti-
isparent, four-sided double pyramids (octahe-

alum is a combination of two different salts, —
it is a *double salt*. The two salts,
sulphate of potassa and sulphate
of alumina, have united *chemically*
together, for a new body
with new properties is formed
from them; they have united
chemically with each other, for
definite quantities of both salts
have entered into combination,
half an ounce of sulphate of potassa, and an
f sulphate of alumina; or, more accurately,
$D, S\,O_3$, and 1 at. $Al_2\,O_3, 3\,S\,O_3$. Alum is diffi-
luble in cold water, easily so in hot water, has
reaction, and, like all the salts of alumina, has
gent taste.

ig. 138.



262. *Experiments with Alum.*

iment a. — Heat a small crystal of alum before
v-pipe; it foams and melts, forming a white
nass (burnt alum), the foaming is owing to the
ion of the water of crystallization, which con-
nearly one half of the weight of the alum.

iment b. — Hydrate of alumina is precipitated
nate of soda from alum, in the same manner
sulphate of alumina.

iment c. — Boil half an ounce of Brazil-wood
n minutes, in six ounces of water; decant the
n, and dissolve in it half an ounce of alum; it

thereby acquires a more brilliant red color. Now add to it a solution of carbonate of potassa or of soda, as long as any precipitate is produced; this precipitate is of a fine red color, and, when dried, constitutes the Brazil-wood lake of commerce. In a similar manner colored precipitates (*lakes*) are obtained from other vegetable coloring-substances. This example serves to show the powerful *attraction* which alumina has for *coloring matter*. Almost all colors of the animal and vegetable kingdom may be precipitated by alumina from their solutions, which accounts for the great importance of the alumina salts in dyeing and calico-printing. For this purpose the *acetate of alumina* is very frequently substituted for alum, because the feeble acetic acid more readily leaves the alumina than the strong sulphuric acid does. It is obtained by mixing together a solution of acetate of lead and sulphate of alumina (or alum), whereby, by double elective affinity, *soluble acetate of alumina* (alum mordant) and *insoluble* sulphate of lead are formed.

Experiment d. — Moisten a piece of alum (or clay or alumina) with a drop of a solution of nitrate of cobalt, and heat it before the blow-pipe; the nitric acid is driven off, but the oxide of cobalt which remains behind imparts a *beautiful blue* color to the compound of alumina. This fact is frequently taken advantage of as very accurate means of detecting alumina. By a similar process, a valuable and very beautiful blue pigment is prepared, called *smalts.*

Another splendid blue pigment, *ultramarine*, has been made within a few years, by heating to redness a mixture of alumina, sulphuret of sodium, and a trace of iron. This pigment must be carefully kept from contact with acids, as they would evolve from it sulphuretted hydrogen, and destroy the color.

263. Alum is not prepared on a large scale directly om clay and sulphuric acid, but from rocks containng alumina and also sulphur (pyrites); for instance, luminous slates or shales. If these rocks are allowed o remain for some time exposed to the air (*weatherng*), or are moderately heated (roasted), there is formed rom the sulphur sulphuric acid, which now combines with the alumina.

264. Alum affords a fine example for elucidating the principle of so-called *isomorphism*. For instance, we are able to replace the potassa in the alum by another simple atomic base, namely, soda or ammonia, or to replace the alumina by another sesquibase, namely, sesquioxide of chromium, or sesquioxide of iron, without thereby changing the octahedral crystalline form. We thus obtain the following kinds of alum: —

Potassa alum,	consisting of	sulphate of	alumina	+	sulphate of	potassa.
Soda alum,	"	"	"	+	"	" soda.
Ammonia alum,	"	"	"	+	"	" ammonia.
Chrome alum,	"	sulphate of	chrome	+	"	" potassa (soda or ammonia).
Iron alum,	"	sulphate of	iron	+	sulphate of	potassa (soda or ammonia).

These combinations are said to be *isomorphous* (from ἴσος, *equal*, and μορφή, *form*), or having the same form, because they possess a similar *constitution* and the same *crystalline form* (octahedron). The term alum is now applied, also, to some of the double salts, in which no alumina is present. The three first of the alums mentioned, have a white color, chrome alum, a deep ed, and iron alum, a pale violet color. They may asily be prepared by dissolving together in water their imple constituent salts, in proper proportions, and utting the solution aside to crystallize.

Occurrence of Alumina in Nature.

265. Next to silica, alumina occurs most frequently in nature, and, indeed, not only in clay and loam, but also in rocks and minerals; for instance, in the well-known gray-colored clay-slate, porphyry, &c. *Felspar* must be regarded as the most important of the alumina minerals, and is found in greater or less quantity in granite, gneiss, mica-slate, and other rocks. In its constitution it has the greatest similarity to alum, except that it contains silicic, instead of sulphuric, acid.

Alum (anhydrous) ($K O, S O_3 + Al_2 O_3, 3 S O_3$);
Felspar ($K O, Si O_3 + Al_2 O_3, 3 Si O_3$).

Felspar, like all other stones, is finally disintegrated by the influence of air and water, and by heat and cold; it weathers, as the miners say, or is dissolved, and the silicate of potassa is thereby gradually removed by the water, so that, as the result of this decomposition, clay or loam remains behind ($Al_2 O_3, 3 Si O_3$). When the farmer lets his ploughed land lie *fallow*, that is, remain uncultivated for some time, he by this means accelerates the weathering; soluble salts of potassa, soda, lime, and other salts, are thereby formed from the constituents of the soil, and to these salts especially is to be attributed the greater fertility of fallow land over that which has been exhausted by cultivation.

266. Glucinum, Yttrium, Zirconium, Thorium, and the recently discovered Erbium, Terbium, and Norium, are very rare elements, the combinations of which with oxygen are white, insoluble, and earthy, like aluminum, and are called Glucina, Yttria, Zirconia, &c.

RETROSPECT OF THE EARTHS (ALUMINA, &c.).

1. The earths are combinations of the metals of the earths with oxygen.

2. They are entirely *insoluble* in water.

3. They do *not* combine with carbonic acid.

4. The most important of these earths is *alumina*, which, combined with silica (*clay*, *loam*), forms a principal ingredient of arable land, and of many kinds of rocks.

5. Alumina is a much weaker base than the alkalies and alkaline earths.

6. Weak bases, as if they were acids, combine with strong bases.

7. Many bodies may, in chemical combinations, replace another body, atom for atom, without a change of the crystalline form taking place (*isomorphous substances*).

8. *Neutral salts* are salts in which, for every atom of oxygen which the base contains, there is an atom of acid.

9. Many neutral salts may combine with one or several atoms of acids; such combinations are called *acid salts*.

10. There are also combinations of neutral salts with one or more atoms of bases; they are termed *basic salts*.

11. When two different salts unite chemically with each other, they are called *double salts*.

RETROSPECT OF THE (LIGHT) METALS HITHERTO CONSIDERED.

1. The metals of the alkalies, of the alkaline earths, and of the earths, are called *light metals*, because they are *specifically lighter* than the other metals.

2. They never occur in nature as pure metals, neither as pure oxides (with the exception of alumina), but always as *salts*, and constitute, together with silica, the principal portion of our earth.

3. Of all bodies, they have the greatest affinity for *oxygen*, and form with it oxides, which (with the exception of the earths) *dissolve* in water.

4. The oxides of the metals of the alkalies, and of the alkaline earths, are the *strongest bases* (alkalies, alkaline earths).

5. On account of their great affinity for oxygen, the preparation of the light metals is very difficult, since the combination between the metal and oxygen can only be destroyed in the strongest charcoal-fire, or by the galvanic current. Only potassium, sodium, and aluminum are as yet accurately known.

6. Until the year 1807 the alkalies and earths were regarded as simple bodies; but at that time the English chemist, Davy, succeeded in resolving them into metals and oxygen, by means of the galvanic current.

7. *Most* of the light metals are able to decompose water, even at ordinary temperatures, and without the aid of an acid; that is, to withdraw from it the oxygen, and consequently liberate the hydrogen.

LAWS OF CHEMICAL COMBINATION.

Before proceeding to the consideration of the other metals, it will be well to revert to the laws of chemical combination, often mentioned in the foregoing pages, and to reduce them to a methodical system.

267. *Classification of Chemical Combinations.* — As innumerable words may be formed from the twenty-six

tters of our alphabet, so likewise innumerable com-
ounds may be prepared from the sixty-two chemical
ements. These may be classed into three great di-
isions. Combinations of the *first order* are formed
hen elements unite with elements; to this belong,
r instance, acids and bases. When these are com-
ined together, we obtain combinations of the *second*
rder, for instance, *salts*. From the union of the salts
ith salts are produced combinations of the *third order*,
or instance, double salts. We find something quite
nalogous to this in the construction of our language.
rom letters we form *syllables*, from syllables single
ords, and from single words *compound words*.

268. *When bodies combine chemically with each other,*
t is always in certain fixed and invariable proportions.
Water, in whatever condition it may exist, whether in
prings or in the sea, as ice or vapor, is uniformly com-
posed of 12½ ounces of hydrogen and 100 ounces of
oxygen. When artificially prepared by burning hydro-
gen in oxygen gas, exactly the above proportion of each
gas is required, that is, 12½ grains, ounces, or pounds of
ydrogen are required for every 100 grains, ounces, or
ounds of oxygen. If 13 ounces of hydrogen are taken,
alf an ounce of hydrogen remains behind; or if 101
unces of oxygen are taken, then an ounce of oxygen
mains behind. Quicklime, whether prepared from
arble or limestone, from chalk or oyster-shells, invari-
bly contains 250 ounces of calcium and 100 ounces of
xygen; and sulphuric acid, whether manufactured by
e Nordhausen method, from green vitriol, or accord-
g to the English method, by the combustion of sul-
ur, always contains 200 ounces of sulphur to 300
unces of oxygen.

269. It has also been ascertained, by the most reli-
le *investigations, how* many parts by weight of th

other elements combine with 100 parts by weight of oxygen. Since these quantities, as will hereafter appear, are of great importance in chemistry, the numbers representing those of the most common elements are given, as follows: —

100 ounces of oxygen, = O, combine with

12½	ounces of	hydrogen,	or H.	489	ounces of	potassium,	or K.
175	"	nitrogen,	" N.	290	"	sodium,	" Na.
75	"	carbon,	" C.	225	"	ammonium,	" NH_4.
200	"	sulphur,	" S.	250	"	calcium,	" Ca.
400	"	phosphorus,	" P.	855	"	barium,	" Ba.
443	"	chlorine,	" Cl.	158	"	magnesium,	" Mg.
1000	"	bromine,	" Br.	171	"	aluminum,	" Al.
1586	"	iodine,	" I.	350	"	iron,	" Fe.
325	"	cyanogen,	" Cy.	345	"	manganese,	" Mn.
136	"	boron,	" B.	368	"	cobalt,	" Co.
277	"	silicon,	" Si.	369	"	nickel,	" Ni.
407	"	zinc,	" Zn.	1350	"	silver,	" Ag.
735	"	tin,	" Sn.	1232	"	platinum,	" Pt.
1294	"	lead,	" Pb.	2458	"	gold,	" Au.
1330	"	bismuth,	" Bi.	328	"	chromium,	" Cr.
396	"	copper,	" Cu.	937	"	arsenic,	" As.
1250	"	mercury,	" Hg.	1613	"	antimony,	" Sb.

These numbers are called *combining proportionals*, because they express the proportion in which an element chemically combines with 100 parts of oxygen. If we now wish to ascertain the composition of potassa, or of oxide of mercury, we have only to refer to the table, and we find, that in potassa 489 ounces or parts of potassium combine with 100 ounces or parts of oxygen, and that in the oxide of mercury, 1250 ounces of mercury combine with 100 ounces of oxygen.

Accordingly, the elements with the smaller proportional numbers must be regarded as more powerful than those with larger proportional numbers. Potassium, for instance, is 2½ times stronger than mercury, since 489 *ounces* of it unite with the same quantity of oxygen *that 1250* ounces of mercury do.

270. *Equivalents.*—Further experiments have led to the surprising discovery, that these numbers not only indicate in what proportion the elements combine with oxygen, but also in what quantities they combine *with each other.* These quantities are the same as those of the proportional numbers. 12½ ounces of hydrogen combine exactly with 100 ounces of oxygen, forming water; with 200 ounces of sulphur, forming sulphuretted hydrogen; with 443 ounces of chlorine, forming muriatic acid. The same quantity of sulphur which, with 300 ounces of oxygen, formed sulphuric acid, yields, with 489 ounces of potassium, sulphuret of potassium, with 350 ounces of iron, sulphuret of iron, and with 1250 ounces of mercury, sulphuret of mercury (cinnabar). If the iron is heated with cinnabar, the sulphur passes to the stronger iron, and the mercury is set free. 350 ounces of iron are thus just sufficient to decompose 1450* ounces of cinnabar, and consequently to liberate 1250 ounces of mercury. If more iron is employed, a portion of it remains uncombined; if more cinnabar, a part of it remains undecomposed. *When in a chemical combination one element replaces another, it always happens in the quantities specified by the combining proportionals.*

For 100 dollars can be bought 6 ounces of gold, or 12 ounces of platinum, or 100 ounces of silver, or 1,500 ounces of mercury; consequently, 6 ounces of gold have the same mercantile value as 12 ounces of platinum, or 100 ounces of silver, &c. The same principle holds good in chemistry. 350 ounces of iron, 489 ounces of potassium, or 1250 ounces of mercury, combine with 100 ounces of oxygen; accordingly, 350 ounces of iron have the same chemical value as 489 ounces of potassium, or 1250 ounces of mercury. This is the reason why these numbers are likewise termed *equivalents* (from *æquus*, equal, and *valor*, value). Thus, by one equivalent of oxygen is to be understood 100 parts of it by weight; by one equivalent of iron, 350 parts by weight; and by one equivalent of mercury, 1250 parts by weight, &c.

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* Cinnabar is composed of mercury 1250 + sulphur 200 = 1450.

271. *The same law of equivalent proportion applies also to the chemical combinations of the second and third order*, to which the process of a neutralization of a base by an acid, and the capacity of saturation of acids, referred (§ 200). When the basic properties of a base, and also the acid properties of an acid, have disappeared, then these two bodies have united with each other in precisely those quantities which are *determined by the natural law.* The amount of this quantity for each body may easily be ascertained by adding together the equivalent numbers of their component parts.

Chalk is carbonate of lime $(Ca\,O,\ C\,O_2)$.

Lime consists of		*Carbonic Acid* consists of	
1 eq. of calcium =	250	1 eq. of carbon =	75
and 1 eq. of oxygen =	100	and 2 eq. of oxygen =	200
Combining number of $Ca\,O$ =	350	Combining number of $C\,O_2$ =	275

That is, in chalk 350 ounces of lime are always combined with 275 ounces of carbonic acid, and exactly the same proportion must be used in the artificial preparation of chalk from its constituents. The combining proportion, or equivalent number, of chalk is accordingly = 625.

If we wish to convert chalk by common sulphuric acid into *gypsum* $(Ca\,O,\ S\,O_3)$ we must first seek for the proportional number of the acid. We commonly find in it one equivalent of anhydrous sulphuric acid, united with one equivalent of water.

The constituents of sulphuric acid are	The constituents of water are
1 eq. sulphur = 200	1 eq. hydrogen = 12½
and 3 eq. oxygen = 300	1 eq. oxygen = 100
Eq. of SO_3 is thus = 500	Eq. of HO is thus = 112½

Consequently, the combining proportion of common sulphuric acid is 612½. This quantity just suffices to convert the above obtained 625 ounces of chalk into sulphate of lime. The carbonic acid which thereby escapes amounts to 275 ounces.

Gypsum combines always with two equivalents of water of crystallization; its constituents are, consequently, —

1 eq. of CaO = 350
1 eq. of SO_3 = 500
and 2 eq. of HO = 225
Equivalent number of cryst. gypsum = 1075 = $CaO, SO_3 + 2HO$.

If you heat it, the water is expelled, and there remains for calcined or anhydrous gypsum the equivalent 850. It is evident that water enters into chemical combinations with the acids, bases, or salts, not as being essential to their constitution, but only as forming a portion of them.

Previously to the discovery of this law, hardly fifty years ago, it could only be ascertained by laborious trials how much of one body was required to combine with another, or to replace another; it is now only necessary to refer to the table of the proportional or equivalent numbers to ascertain *beforehand* the quantity to be employed.

272. *Multiple Proportions.* — Many elements have the capacity of combining with three, four, five, or even more proportions of oxygen, sulphur, chlorine, &c., thus producing the different oxides, sulphides, chlorides, &c., described in section 154. This would

and *invariable* proportions.

If we ascend a hill, it is a
many or few, long or shor
tion is not interrupted by
but on mounting a flight of
minate and regular number o
In like manner, bodies which
tions with another body do so
variable quantities, and such
place in ratios of 1½, 2, 2½, 3,
of 1¼, or 1¾, or 1⅞, &c. The
were, only by whole or half st

75 oz. of carbon form, with	100 oz. of oxygen,	car
	150 " "	ox
	200 " "	car
75 oz. of nitrogen form, with	100 oz. of oxygen,	nit
	200 " "	nit
	300 " "	nit
	500 " "	nit
375 oz. manganese form, with	100 oz. of oxygen,	pro
	150 " "	ses
	200 " "	hy

It is obvious that these numbers stand in a very simple ratio to each other, and that the larger numbers are a multiple of the smaller number; this is expressed by calling it the *law of multiple proportions.*

273. *Gaseous bodies always combine with each other in certain volumes.* The volume of the gases is very often less, after combination, than the sum of their volumes in their separate state.

Examples.

From 1 vol. of chlorine and 1 vol. of hydrogen are formed 2 vols. of hydrochloric acid gas.

From 2 vols. of hydrogen and 1 vol. of oxygen are formed 2 vols. of aqueous vapor.

From 3 vols. of hydrogen and 1 vol. of nitrogen are formed 2 vols. of ammoniacal gas.

From 6 vols. of hydrogen and 1 vol. of sulphur are formed 6 vols. of sulphuretted hydrogen gas.

Thus the same constancy characterizes the combinations by volumes as those by weight, and they are marked by a still greater simplicity. And if it were possible to convert all bodies into gases, probably a similar simple proportion by measure or volume would be observed in all chemical combinations.

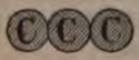
274. *Atoms.* — After having proved by a vast number of facts, the result of the most laborious investigations, that chemical combinations always take place according to fixed volumes and weights, the cause of this wonderful immutability is sought for. A thinking man, when he knows *that* a thing happens, and *how* it happens, will always inquire, *Why* is it thus, and not otherwise? This question could not be solved by any effort of experiment and observation; but reflection has enabled us to arrive at an idea by which we can ex-

plain to ourselves this regularity and unchangeableness. This idea has received the name of the *atomic theory.* It is as follows:—

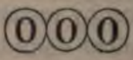
1.) Every substance is composed of small particles, which lie in contact with each other, and are called *atoms;* between these atoms there are interstices or pores. In light bodies the atoms are more remote from each other, and the interstices are larger, than in heavy bodies. When substances are subjected to cold or pressure, the atoms approximate more closely, and the bodies become denser and specifically heavier, while, if heated, the atoms separate from each other, the pores become larger, and the bodies consequently more expanded and specifically lighter. The atoms are farthest distant from each other in gases and vapors; in steam, for instance, they are 1700 times more remote than in the liquid water, since the former occupies 1700 times more space than the latter.

2.) Simple bodies have *simple atoms,* compound bodies *compound atoms.* For example, —

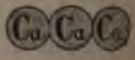
Carbon:



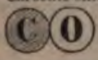
Oxygen:



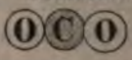
Calcium:



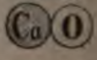
Carbonic oxide:



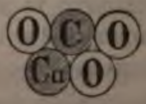
Carbonic acid:



Lime:



Carbonate of lime:

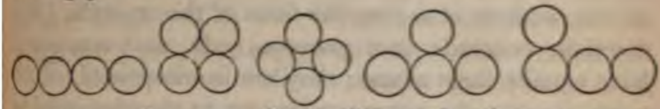


3.) These small particles, of which the mass of a body consists, cannot be further divided into yet smaller parcles. Thus is explained the name *atomus* (that which annot be divided).

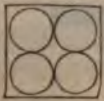
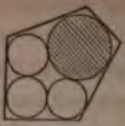
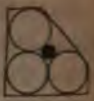
4.) They are so *small* that they can neither be seen nor counted, even by means of the most powerful magnifying-glass; and they have, therefore, only an imaginary existence.

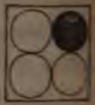
5.) When a solid body separates slowly from a fluid, its atoms have time to arrange themselves beside each other in a definite manner, and we obtain *regular crystals;* but on becoming suddenly solid, an *irregular* disposition of the atoms takes place, and the body appears *amorphous* (vitreous or pulverulent).

6.) The position of the atoms towards each other *may be varied.* As four balls may be put in the following positions, —



so atoms also may lie beside each other, arranged sometimes in one and sometimes in another manner. Thus is explained why one and the same substance may often appear in different forms of crystallization, or with a different structure, consequently in two different states (dimorphous). Sulphur, at ordinary temperatures, crystallizes from its solutions in octahedrons; but when fused, it crystallizes on cooling in oblique prisms (§§ 125, 126). A newly forged iron axle has a fibrous texture, but after being used for some time its texture becomes granular.

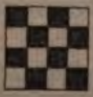
7.) The atoms of different bodies have also probably a different *size.* A regular square may be constructed of four peas;  but if we replace one of the peas by a bean  or by a mustard-seed, 

then in both cases the regular form is disturbed; it remains, however, unchanged, when a ball of lead of the same size as the pea is substituted for it, 

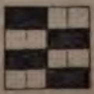
though the square will now present a different appearance. This is an illustration of what occurs with the atoms. We have seen, in the case of the alums, that the potassa may be replaced by soda or ammonia, or the alumina by sesquioxide of chromium or sesquioxide of iron, without changing the form of the crystals. We therefore conclude that potassa, soda, and ammonia have equally large atoms; they are isomorphous (of the same shape); the same applies also to alumina, and to sesquioxide of chromium and of iron. If we see, on the contrary, that a change takes place in the form of the crystals when we replace one body by another, we thence infer that there is an unequal size of the atoms in these bodies.

8.) The *isomeric* state of bodies is explained very simply by the atomic theory. The most manifold and regular grouping may be produced on a chess-board by transposition of the white and black squares; for instance, —

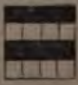
a.



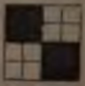
b.



c.



d.



Each figure is composed of eight white and eight black squares, but though the absolute number is the same, the grouping is different. In *a*, one and one, in *b*, two and two, in *c* and *d*, four and four, squares are so joined together as to present a different appearance. If we imagine these squares to be atoms, we obtain an idea of isomeric bodies, and it is thus rendered clear how there may be bodies of the same constitution and form, yet presenting an entirely different appearance, and possessing different properties. Those exceedingly dissimilar bodies, caoutchouc (gum elastic), petroleum, and illuminating gas, afford a striking example of external difference and interior conformity. They have the same constituents (carbon and hydrogen) both in quality and quantity.

9.) The atoms of the different bodies must finally possess also *weight*, and, indeed, very different degrees of it. If a piece of chalk, containing perhaps a million of atoms, has a fixed weight, so also must the smallest particle of it possess weight, however slight it may be; for a body having weight can never be formed of a body having no weight. Chalk always contains 350 ounces of lime, and 275 ounces of carbonic acid. If a large piece of chalk has this constitution, so a smaller piece, even the minutest particle, must unite in the same proportions. If we suppose chalk to be composed of one atom of lime, and one atom of carbonic acid, we ascribe to the atom of lime a weight of 350, and to the atom of carbonic acid a weight of 275. In 350 ounces of lime are always contained 250 ounces of calcium and 100 ounces of oxygen; this combination, also, is to be regarded as consisting of equal atoms; accordingly, one atom of calcium weighs 250, and one atom of oxygen 100. Finally, in 275 ounces of carbonic acid are always contained 75 ounces of carbon united with 200 ounces of oxygen; wherefore 75 is to be regarded as the weight of an atom of carbon, and 200 as that of two atoms of oxygen.

The numbers are exactly the same as those given in the list of proportional or equivalent numbers. Thus these numbers in an atomic point of view may be regarded as the *relative weight of the atoms;* hence the third and simplest name for them, *atomic weights.*

HEAVY METALS.

FIRST GROUP OF THE HEAVY METALS.

IRON, FERRUM (Fe).

At. Wt. = 350. — Sp. Gr. = 7.

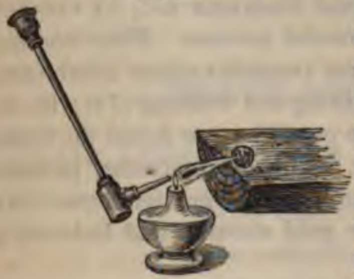
275. If gold is called the king of metals, *iron* must be deemed by far the most important and useful subject in the metallic realm. Iron was formerly regarded as the symbol of war, and received the name of Mars, and the symbol ♂; but who does not know that it has now attained also a great, an indescribably great importance in the peaceable occupations of men? It is not only converted into swords and cannons, but into ploughshares and chisels, and into a thousand other implements and machines, from the simple coffee-mill to the wonderful steam-engine. It is the ladder upon which the arts and trades have mounted to such an extraordinary height. It is the bridge upon which we now glide over mountains and valleys with the rapidity almost of magic.

Pure gold is found on the surface of the earth, and it is only necessary to free it from earthy admixtures to obtain it in a pure metallic state. Not so with iron. The ore in which this lies imbedded must be procured from the earth by skilful operations, and its oxygen expelled by ingenious methods, and by exposure to the hottest fire, in order to convert it into metallic iron; the latter must again be fused and refined by different operations before it can be forged and welded. Gold is presented to men by nature as a gift, but iron must be struggled for by the most laborious toil, by exertion both of the bodily and mental powers. Thus iron has become a blessing to those countries whose inhabitants are occupied with the mining and working of it; for, as history teaches, in those countries are found the blessings attendant on labor, health, contentment, prosperity, and intellectual culture, in a far greater degree than in those countries where gold abounds and industry is neglected.

In another respect, also, iron, of all the heavy metals, appears to be the most important to mankind. It is the only metal which is not injurious to the health, the only metal which forms a never-failing constituent of the body, especially of the blood; the only metal, finally, which is found everywhere on the earth, in all stones and soils, and in almost every plant. Although we are ignorant wherein consists the influence which it exercises upon the life of animals and plants, yet its universal diffusion must lead us to conclude that it has pleased the Highest Wisdom to invest iron with an importance for organic life similar to that possessed by common salt, lime, phosphoric acid, and some other substances.

flame of the blow-pipe, directed u
comes red-hot, and the heat spre
whole mass, as is apparent from
whic
heat.
ing a
most
bakes
mass
18¾ g
grains
with
gen.
these
obtain 350 grains of iron (1 atom)
oxygen (¼ atom), or four atoms of ir
oxygen. This body may be termed
In the protoxide of iron, one atom o
combines with one atom of oxygen (
the suboxide may be regarded as

Fig. 139.



, the well-known *iron cinders.* It is a mix-
protoxide and *sesquioxide* of iron. The pro-
(Fe O) cannot be prepared in a pure state by
ethod, as sesquioxide is always simultaneously
; but from the color of the suboxide and of the
xide, it may be inferred that it has a black color.
rceive this color, also, in all those rocks which
protoxide of iron, generally in combination
licic acid. Almost all black and green stones,
tance, basalt, clay-slate, greenstone, serpentine,
ve their color to protoxide of iron.

ron ore, which has the same constitution and the
lack color as iron cinders, occurs abundantly in
laces. It is called *magnetic oxide of iron*, and is
y attractable by the magnet, but is itself likewise
tic. A small magnet may be prepared by placing
of magnetic iron ore (loadstone) between two
iron, when the magnetic force passes from the
nto the iron. The celebrated Swedish iron is
obtained from this variety of iron ore.

eriment c. — Iron cinders, when exposed for a
me to the exterior or oxidizing blow-pipe flame,
covered with a red pulverulent coating; they
et more oxygen from the air, and become *sesqui-*
f iron ($Fe_2 O_3$).

eriment d. — The sesquioxide of iron may be pre-
nore easily in the following manner. Place a
of green vitriol upon charcoal, and heat it until
become of a brownish-red color. The water
lphuric acid escape, and the protoxide of iron
remaining behind absorbs one half as much
xygen, and becomes converted into sesquioxide
($Fe_2 O_3$). The red color of the latter is more
brought out by rubbing it on paper with the

nail. In the same manner, sesquioxide of iron remains behind when green vitriol is heated in the preparation of oil of vitriol; this forms an article of commerce under the name of *caput mortuum*, English or polishing rouge, and is a favorite and cheap pigment for varnish, and is also used in the polishing of glass and metals.

Sesquioxide of iron occurs native in many places of the earth, sometimes crystallized, as in *iron-glance;* sometimes compact, as in *red iron-stone;* or radiated, as in *red hematite;* or earthy, as in *red ochre.* It is often also mixed with clay, and is then called *clay iron-stone.* The coloring matter of red stones or earths is owing to the presence of sesquioxide of iron. Many of the above-named bodies form immense beds in the interior of the earth, and are used as valuable ores (*specular iron*) for the manufacture of iron.

Experiment e. — Introduce some iron filings into a tumbler, and fill it with spring-water; the iron will gradually lose its lustre, and assume a black color; it is converted into magnetic oxide of iron. Repeat this experiment with water that has been boiled; in this, the iron will retain its metallic lustre. The cause of this difference is owing to the air and carbonic acid, which are present in all spring-water, and slowly oxidize the iron. These gases are expelled by boiling, therefore no oxidation takes place in water that has been boiled.

Experiment f. — If you now pour off the water, so that the iron comes in contact also with the air, rust begins to form upon it. The iron absorbs so much oxygen that it becomes a sesquioxide; it also absorbs a definite quantity of *water* (3 atoms), which may be regarded as the cause of the yellow color of rust. Rust is therefore *hydrated sesquioxide of iron* ($Fe_2 O_3, 3 H O$).

If you keep the iron moist, and stir it round several times every day, it will, after a time, be completely converted into rust.

This combination frequently occurs also in nature, and is used as an excellent iron ore, under the name of *brown iron ore.* When mixed with clay it is called *yellow clay iron-stone*, *yellow ochre*, &c. The yellow or brown color which we see in so many stones when they are exposed to the air, the yellow or brown color of the soil, loam, or sand, always proceeds from the hydrated sesquioxide of iron. The weathering of black varieties of stone to a brown stratum, and finally to a yellow arable soil, will now no longer appear strange; the black protoxide of iron contained in them is gradually oxidized into a yellow hydrated sesquioxide of iron.

Experiment g.— Put a small quantity of the magnetic oxide of iron obtained at *b*, or some iron filings, into a phial; fill the latter with artificial Seltzer-water, and let it stand, well stopped up, for one day. The white flakes which deposit on the bottom of the phial are *carbonate of the protoxide of iron*, formed from the protoxide of iron of the iron cinders, and from the carbonic acid of the Seltzer-water. The chemically combined water in this case communicates a white color to the black protoxide of iron. The clear liquid also contains some of the carbonate of iron in solution, as is evident from the *inky taste* peculiar to solutions of iron. It is then to be poured into a tumbler, and left for some time exposed to the air. In proportion as the free carbonic acid escapes, the surface is covered with a delicate white pellicle, the color of which gradually changes to yellow, then to red and violet; finally, the pellicle assumes a yellowish-brown color, and falls as rust to the bottom. *Protoxide of iron attracts oxygen with great avidity, and is converted into magnetic oxide of iron, and finally into hydrated sesquioxide of iron.* The salts of protoxide of iron act also in the same manner; this is the reason of their becoming yellow by long keeping, or by exposure to the air. A very thin pellicle of magnetic oxide of iron gives a yellow reflection; a thicker pellicle, a red or brown, and a still thicker one, a violet and blue reflection; this explains the iridescent changes of color presenting such a beautiful appearance on the surface of standing waters. In those places where spring-waters flow over stones containing iron, natural solutions of carbonate of iron (*chalybeate waters*) frequently occur, which are likewise decomposed by the air. This decomposition of the carbonate of iron is the source of the brown mud which is deposited in large quantities from some waters. By the accumulation of this mud, large beds of hydrated sesquioxide of iron are formed, known under the name of *bog-iron ore*, and from which iron is worked. This ore usually contains also some phosphoric acid.

The *carbonate of protoxide of iron* is found in many countries in the form of a light gray massive stone, and in such large quantities that iron is obtained from it. The famous Styrian steel is principally prepared from this ore, which is called *spathic iron ore*, or spherosiderite. Mixed with clay, it very frequently occurs associated with pit-coal, and it is from this ore that most of the English iron is obtained.

277. In attending to the combinations which iron yields with oxygen, we have also become acquainted with the most important iron ores from which iron is prepared on a large scale. They are the following:—

$Fe\,O + Fe_2\,O_3$, or magnetic iron ore.

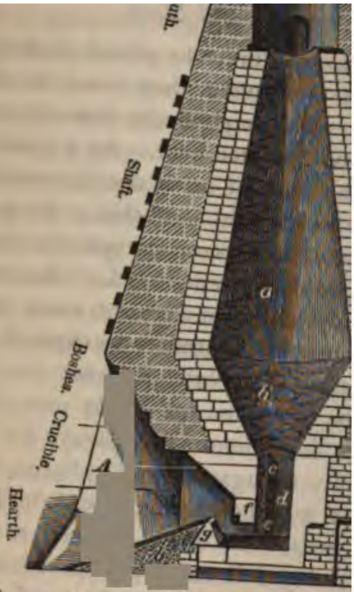
$Fe\,O, C\,O_2$, or spathic iron (clay iron-stone, spherosiderite).

$Fe_2\,O_3$, or specular iron (red hematite, iron-glance, &c.).

$Fe_2\,O_3 + 3\,H\,O$, or brown iron ore (yellow iron-stone, yellow ochre, &c.).

Cast-Iron, Bar-Iron, and Steel.

278. *Working of Iron.* — In order to extract metallic iron from the ores just mentioned, they must be deprived of their oxygen. This is generally done by exposing them with charcoal to a red heat. As a general rule, a mixture of several kinds of ore is used for smelting, because experience has taught that this process is then conducted more easily and more completely than when only one kind of iron ore is employed. The ores, containing carbonic acid, water, or sulphur, must previously be heated in appropriate furnaces to expel these volatile gases (*roasting of the ores*). It must also be borne in mind that the iron ores are never pure, but always contain foreign ingredients (*gangues*); for instance, silica, clay, lime, manganese, phosphorus, &c. *Silica* especially forms a principal ingredient in iron ores. This does not melt even when exposed to the hottest furnace-fire; and yet it must be melted, that the iron may flow from the ores, and be obtained as a coherent mass. This is effected by the addition of a base, commonly lime, with which the silicic acid will combine. A lime-glass is formed, and if loam or clay be present also an alumina-glass, both of which, when combined, melt more readily than each separately, and flow off as *slag*. The substance which forms this fusible compound is termed the *flux;* and the combination of the prepared ore and the flux is called the *mixture*. Alternate layers of this mixture, and of wood-



The portion *a* of the blast-furnac
b is the *boshes*, *c* is the *crucible* par

consumed, on access of air, into carbonic acid, and occasions the bright flame which issues from the top.

In the boshes, where the greatest heat is evolved, the reduced iron melts and falls in drops upon the hearth, together with the silica, lime, and clay; these form a slag, which floats on the molten iron, and is drawn off at *i*. The melted iron is suffered to flow off from time to time, by a small opening made in the side-wall of the hearth. After having heated to a hundred degrees or more the air necessary for burning the charcoal or coke, it is forced at *d*, by means of large bellows, or other *wind apparatus*, into the furnace, in which a heat of perhaps 1200° or 1400° C. may be produced. In proportion as the melted iron and the slags are removed from beneath, fresh charges of ore, lime, and charcoal are introduced at the top, and in this manner the smelting often continues uninterruptedly for five or six years, according as the furnace holds out.

Iron Ore, Flux, Fuel,	Iron + — Carbon,	Oxygen + — Carbon,	Silica (clay). Lime (clay). — —
Product,	Carburetted Iron (cast-iron).	Carbonic Oxide and Carbonic Acid.	Silicate of Lime and Silicate of Alumina } Slag.

The slag from the blast furnaces has generally a green or blue color, owing to the protoxides of iron and of manganese there dissolved in it. They are frequently formed into square blocks, and used for building-stones.

279. *Cast or Crude Iron.* — The metal obtained by the above process is by no means pure iron, but a chemical mixture of iron and carbon. A hundred-weight of iron takes up, at the hottest white heat, from about four to five pounds of carbon, and likewise some silicon from the silicic acid, some aluminum from the

clay, and sometimes also a trace of sulphur, phosphorus, arsenic, &c., when these were contained in the iron ore. Cast-iron, thus obtained, is characterized by the following properties.

a.) It is *fusible* at a glowing white heat (wrought-iron and pure iron are not); therefore it is especially adapted for those iron articles which are made by casting. For remelting iron on a small scale, graphite crucibles are made use of, but on a large scale shaft-furnaces (*Schachtöfen*), or the so-called cupola-furnaces.

b.) Cast-iron is *brittle, and can neither be forged nor welded* (bar-iron and steel may be bent, forged, and welded). The application of cast-iron must, therefore, be limited to the manufacture of such articles as are not exposed to being bent, or to strong concussions. Very recently, however, a method has been discovered for imparting to cast-iron a certain degree of flexibility, and even of malleability, by exposing it for several days with iron scales or spathic iron to a red heat. The term *malleable cast-iron* (fonte malléable) has been given to this kind of iron.

There are *two kinds of cast-iron* in commerce, known as gray and white iron. The *gray iron* is almost black, has a granular texture, and admits of being filed, bored, &c.; the *white iron*, on the contrary, is of a silvery whiteness, possesses a lamellar-crystalline texture, and is so hard as not to be acted upon by steel instruments. Crude white iron, by remelting and very slow cooling, is changed to gray; on the other hand, the gray is changed to white iron by being heated and suddenly cooled. Gray iron is best adapted for castings; white iron is the most suitable for the manufacture of bar iron and steel.

280. *Malleable or Bar Iron.*—Cast-iron, by being

eprived of its carbon, is converted into *malleable iron*, and acquires the following very important properties.

a.) Bar-iron possesses great *ductility* and *tenacity*, and may be hammered or rolled into sheets, and drawn out into fine wire, which is not the case with cast-iron.

b.) At a less degree of heat than that of fusion, it becomes *soft*, like wax or glass, so that two glowing pieces may be welded into one. Upon this property rests its capacity of *being welded*, which is possessed by no other known metal, except platinum. All the other metals become fluid instantaneously, as is the case with ice, without undergoing previous softening.

c.) Wrought-iron is sufficiently soft to be worked by steel instruments, and it does *not* become *harder*, if, when heated to redness, it is suddenly quenched in water (steel is thereby rendered brittle).

d.) Wrought-iron is distinguished, moreover, from cast-iron by its *fibrous texture*, composed, as it were, of threads incorporated together; while cast-iron has the appearance of being a baked *granular* mass. But it is a very striking fact that fibrous wrought-iron, by repeated jolts or blows, becomes gradually granular and brittle, as, for example, in the axletrees of carriages. Thus, also, in solid bodies, *their particles or atoms can change their position with regard to each other*, which was formerly supposed to be possible only with liquid bodies. By thoroughly heating and reworking, the former strength and flexibility, as well as the fibrous texture, is restored to the iron.

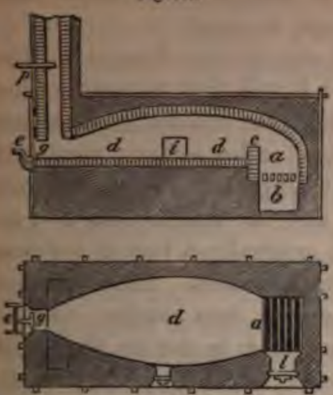
Wrought-iron is not entirely freed from carbon; it contains, however, only from a quarter to a half pound of it for each hundred-weight. Iron entirely free from carbon is softer and more tenacious than bar-iron; thus we see that it is the chemical combination of the carbon with the iron, as in cast-iron, which destroys these two properties of softness and tenacity.

281. *Refinery of Iron.* — 1. *Finery Process.* — The method which is employed for separating carbon from the cast-iron is very simple. The carbon is *burnt out* by heating the iron to fusion, and constantly stirring it while exposed to a current of air, the oxygen of which combines with the carbon, forming carbonic oxide gas. During the operation, a considerable portion of the iron (one quarter) is converted by oxidation into iron cinders, which fuse with the sand, that either adheres to the cast-iron, or is purposely strewed upon the hearth, and form with it a heavy black slag of silicate of magnetic oxide of iron. The iron mass becomes gradually more tenacious, since the iron melts so much the more difficultly the less carbon it contains; and finally, in the form of a loosely coherent mass (the *bloom*) is placed under a loaded hammer, by a few blows of which the remaining slag is pressed out, and the iron particles are formed into a compact mass. The latter is afterwards usually hammered or rolled into bars or bands. This method of converting brittle cast-iron into ductile and malleable iron is called the *finery process.* The object of the refinery is, as has just been shown, to *separate the carbon from the iron.* The annexed scheme serves to render the process more intelligible.

Cast Iron,	Iron ¾,	Iron ¼,	Carbon.
Air,	—	Oxygen,	Oxygen.
Sand,	—	Silica,	
Products,	Wrought Iron,	Slag,	Carbonic Oxide.

2. *Puddling Process.* — For the refining or decarbonizing of larger quantities of iron, the reverberatory furnaces are used, similar to those employed in the preparation of soda (§ 220). As in these furnaces the fuel

Fig. 141.



does not come in contact with the iron itself, a cheaper fuel than charcoal may be made use of, for instance, pit-coal or turf, the ashes of which, if mixed with the iron, would certainly spoil it. These are called *puddling-furnaces*, because the iron must be kept constantly stirred (*puddled*).

282. *Steel.* — *Steel* holds a middle place between cast and wrought iron, both as to the quantity of carbon it contains, and other properties.

a.) If quenched when heated to redness, it is rendered hard and *brittle* (like cast-iron); if cooled somewhat more slowly, it is rendered *elastic*, and if cooled very slowly, it is soft, *ductile*, and *malleable* (like bar-iron).

b.) It is less fusible than cast-iron, and more so than bar-iron.

c.) It contains, in every hundred-weight, from two to two and a half pounds of carbon.

To these properties steel owes its importance as a material for thousands of articles, especially for cutting instruments, since it may be made soft or hard, elastic or brittle, at pleasure. The article manufactured is usually first heated to redness, then suddenly cooled by quenching it in water, and afterwards *tempered* in order to diminish its hardness and brittleness.

Experiment. — Hold a steel knitting-needle in the flame of a spirit-lamp till it is red-hot, and then quickly

The cause of this change
of the ferruginous water (§
forms upon the steel; at fi
a *yellow* appearance, but
and also darker, as the heat
— the dark gray coating
standing of the ferruginous
tion advanced (§ 276) a ste
final result was a brown sub
oxide of iron. A definite de
ticity of the steel correspond
needle when covered with t
hardest and most brittle, an
aspect being in its softest a
The workmen in steel impa
degrees of hardness and ela
and razors are made very
watch-springs, &c., soft and e

283. Steel may be *prepare*

1.) By partly refining

eel may be ornamented by corroding its polished sur-
e with acids, whereby a variety of light and dark
lored shades and impressions will be produced
amaskeening).

From the constituents of bar and cast iron it may be
ferred that steel can be made by an intimate combi-
tion in equal proportions of those two substances.
this manner, indeed, the exterior surface of wrought-
on articles — as, for instance, of agricultural imple-
ents, chains, &c. — can easily be converted into steel,
being heated in melted cast-iron. This object may
attained more easily by strewing ferrocyanide of po-
ssium over the hot iron (§ 292).

Iron, nickel, and cobalt are the only metals which
e attracted by the *magnet*. Magnetism immediately
nishes from bar-iron when it is removed from the
agnet; while steel, on the contrary, retains its mag-
etic power, and does not lose it until heated to red-
ss (*steel magnet*). The magnetic oxide of iron is
kewise attracted by the magnet, owing to the protox-
e contained in it, but the sesquioxide of iron is not
attracted.

Salts of Iron.

284. The protoxide and sesquioxide of iron form
lts with acids; we have, accordingly, two series of
on salts: — *a*) the *salts of protoxide of iron* are gen-
ally green, and consist of one atom of protoxide of
n, and one atom of acid; *b*) the salts of *sesquioxide*
iron are usually of a yellowish-brown color, and con-
t of one atom of oxide and an atom and a half of
id (or 2 : 3).

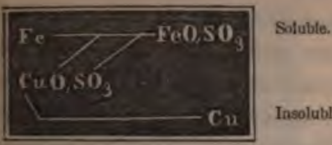
Iron and Acids.

It has already been mentioned (§ 173) that many metals dissolve only in diluted acids, others only in concentrated acids, and that the former take the oxygen requisite for their oxidation from the water, while the latter take it from the acids. Iron, together with manganese, zinc, cobalt, nickel, and tin, belongs to the first-named class of metals, which are called *water-decomposing* or *electro-positive* metals. The mere circumstance, that in the presence of an acid they are able to abstract oxygen from the water, leads to the supposition that they are *more powerful chemical bodies* than those metals which cannot do this. This supposition is in reality confirmed; the electro-positive metals evince a far greater affinity for oxygen, sulphur, chlorine, &c., and their oxides a much greater affinity for the acids, than is exhibited by the other metals and their oxides. It may be well in this place to remind the student that a solution of a metal does not contain a metal as such, but always a metallic salt in solution (§ 160).

285. *Green Vitriol, or Sulphate of Protoxide of Iron* ($Fe\,O, S\,O_3 + 6\,H\,O$).

This salt, which is always formed when iron is dissolved in diluted sulphuric acid, is often called green vitriol, on account of its pale-green color. By slowly evaporating the solution, the salt may easily be obtained in oblique rhomboidal prisms; these crystals contain nearly one half their weight of water of crystallization.

Experiment. — Dissolve 100 grains of blue vitriol (§ 175) in an ounce of water, and introduce into the solution a piece of polished iron, which has been previously weighed; the blue color will gradually change to green, while the iron is covered with a red coating of *copper*. The stronger iron takes from the copper its oxygen and sulphuric acid, and combines with both of them; 32 grains of metallic copper are deposited, while full 28 grains of iron have been dissolved. But 32 is to 28 nearly as 396 (the atomic weight of copper) is to 350 (the atomic weight of iron); accordingly, one atom of copper is replaced by one atom of iron. This process is called *the reduction of a metal by the moist way.* The supernatant liquor contains in solution no longer any copper, but only green vitriol, which may be crystallized by evaporation. Thus is explained the inappropriate name of *copperas*, very commonly applied to sulphate of iron.



Experiments with Green Vitriol.

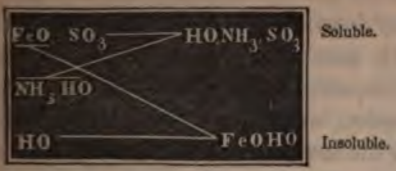
Experiment a. — Let a solution of green vitriol stand for some time in the air; it will gradually assume a yellowish color, and a brownish-yellow substance, hydrated sesquioxide of iron, is deposited. All the other salts of protoxide of iron do the same; namely, *they attract oxygen from the air*, and are gradually converted into salts or sesquioxide of iron. But the acid present is not sufficient to dissolve all the oxide, as this has a greater capacity for saturation, that is, requires more acid for its solution than the protoxide of iron does; therefore, a portion of the oxide formed falls to the bottom. *For the same reason, a sesquioxide or peroxide always separates from the protoxide salts of the other metals, when they are converted into higher oxide salts.* A clear solution may be obtained, by adding a sufficient quantity of acid to dissolve the precipitated oxide.

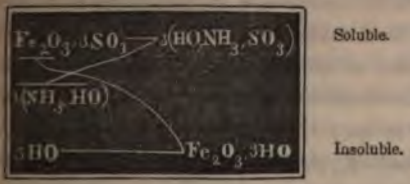
Experiment b. — Boil half an ounce of green vitriol with an ounce and a half of water and one dram of sulphuric acid, in a porcelain bowl, and add a few drops of nitric acid to the solution, until the color of it is changed to yellow; it now contains *sulphate of sesquioxide of iron* in solution, which must be kept for use. The same effect, namely, the conversion of the protoxide into sesquioxide of iron, is thus *quickly* produced by the oxygen of the nitric acid, which in the former experiment was only *slowly* caused by the action of the air. Three atoms of oxygen are withdrawn from the nitric acid, and, accordingly, nitric oxide is produced (§ 162), which has the property of imparting to a solution of green vitriol a dark color. On boiling, the nitric oxide escapes, and is converted in the air into nitrous acid, forming the yellow fumes that are given off during the oxidation.

Experiment c. — Prepare (1.) a diluted solution of green vitriol, (2.) a mixture of one part of a solution of sulphate of sesquioxide of iron and four parts of water (see former experiment), and (3.) a mixture of the first and second; and then add ammonia to each of the three liquids, until they emit a distinct ammoniacal odor. There is formed in the

1. Solution of protoxide of iron, a greenish white precipitate of hydrated protoxide of iron;
2. Solution of magnetic oxide of iron, a black precipitate of hydrated magnetic oxide of iron;
3. Solution of sesquioxide of iron, a yellowish brown precipitate of hydrated sesquioxide of iron.

Ammonia is a stronger base than either protoxide or sesquioxide of iron; for this reason, it abstracts from them their sulphuric acid, and the oxides will be precipitated, since almost all the metallic oxides are insoluble in water. If the metallic oxides, at the moment of their





separation from a combination, meet with water, they readily combine with it, forming *hydrates*. This is the reason why the metallic oxides, which are obtained in the moist way, frequently have a very different color from those prepared in the dry way (by heating to redness). If you heat the hydrate, the water is expelled, and the oxides appear now in their characteristic color. This change of color is well illustrated in the case of common bricks, which, before being burnt, have a yellow color, owing to the presence of hydrated sesquioxide of iron; when burnt, they are red, because the hydrated water is expelled by the heat, and thereby anhydrous sesquioxide of iron is formed, which possesses a red color. If the above precipitates are filtered, a striking change is soon perceptible in the protoxide of iron, its color changing first to a dark green, then to black (magnetic oxide of iron), and finally to brown (hydrated sesquioxide of iron), according to the amount of oxygen absorbed. As already stated, one of the most important properties of protoxide of iron is, that it combines *eagerly with still more oxygen*, a property which, as we have seen, it communicates also to the salts in which it is contained.

The black precipitate of magnetic oxide of iron comports itself in the same manner. But if you boil it previously to filtration, it will retain its black color on drying. In this state it is used as a medicine, under the name of *black oxide of iron.*

Experiment d. — If you pour alcohol upon some bruised nutgalls, the liquor, after a few days, will have a brownish-yellow color, and a very astringent taste. This liquid — called tincture of galls — contains in solution, besides several other ingredients, two organic acids, *tannic acid,* or tannin, and *gallic acid.* Add some of this tincture to a solution of green vitriol, and some of it likewise to a mixture of water and sulphate of sesquioxide of iron; in the former, a *light-colored* precipitate will be formed, which assumes at first a *violet,* and finally a *black* color; but in the second liquid a *black color* is *immediately* produced; and, on standing, a black precipitate will be deposited. This black precipitate consists principally of *tannate* and *gallate of sesquioxide of iron.* By adding to this gum or sugar, common *ink* is prepared, the mucilaginous or saccharine liquid thus obtained holding the gallate and tannate of iron in suspension. The combination of tannin and gallic acid with protoxide of iron is not black, but it becomes so on exposure to the air, since the protoxide is thus converted into sesquioxide. This explains the pale color of fresh ink, and its becoming dark on the paper. If you dip a linen rag first in tincture of galls, and then in a solution of iron, the black precipitate is formed in the fibre itself, and thus adheres so firmly to it that it cannot be washed out again. This is the general method used for dyeing cloth, leather, hair, &c., either black or gray, and for this reason the iron salts, especially green vitriol, have a very extensive application in dyeing and calico-printing.

286. *Nitrate of sesquioxide of iron* $(Fe_2O_3, 3\,NO_5)$ is

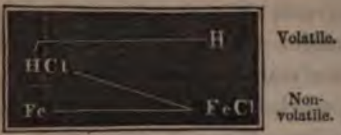
obtained by adding iron filings to diluted aquafortis, as long as they continue to dissolve in it. Nitric acid furnishes an abundant supply of oxygen to the iron, and this takes up as much oxygen as it can bind, and is converted into a sesquioxide. This solution is of a brown color, and is used in dyeing. If some aquafortis is dropped upon cast-iron, steel, or bar-iron, black spots are produced, because the iron, but not the carbon, is dissolved. These spots are darker in cast-iron, and lighter in bar-iron. Hence, to ascertain how much carbon is contained in a sample of iron, you have only to dissolve a weighed quantity of it in diluted nitric acid, and to weigh the charcoal remaining behind.

287. *Acetate of sesquioxide of iron* may be prepared directly, by dissolving freshly precipitated and still moist hydrated sesquioxide of iron in acetic acid. When mixed with alcohol and ether, it forms *Klaproth's ethereal tincture of acetate of iron*, which is sometimes used as a medicine. When the shoemaker pours beer upon iron nails to prepare the iron-black with which he blackens his leather, he obtains acetate of sesquioxide of iron; for on exposure to the air the beer is changed into vinegar, and the iron to sesquioxide. Leather is a combination of the skin with tannin; when the latter meets with the sesquioxide of iron, black tannate of iron (ink) is formed. An iron mordant is now frequently prepared for dyeing purposes, by dissolving iron-rust in wood-vinegar (pyrolignite of iron).

288. *Phosphate of protoxide of iron* is prepared by mixing a solution of green vitriol with a solution of phosphate of soda; the white precipitate produced becomes gradually blue by attracting oxygen from the air (phosphate of the magnetic oxide of iron, blue iron-earth). *Phosphate of sesquioxide of iron* is white, and occurs in the ashes of many plants.

Iron and Chlorine.

289. *Protochloride of Iron* ($Fe\,Cl$), a green salt, is formed by dissolving iron in muriatic acid; *sesquichloride of iron* ($Fe_2\,Cl_3$), a brown salt, by dissolving sesquioxide of iron or hydrated sesquioxide of iron in muriatic acid, or by the addition of chlorine water to protochloride of iron (§ 186). Protochloride of iron is also called muriate of protoxide of iron, and sesquichloride of iron is often called muriate of sesquioxide of iron.



Iron and Cyanogen.

As chlorine combines with iron, so also cyanogen can form combinations with iron. Two of them, *Prussian blue and yellow prussiate of potassa*, have acquired very great importance in the arts.

290. *Prussian Blue, or Ferrocyanide of Iron* ($3\,Fe\,Cy + 2\,Fe_2\,Cy_3$).

If magnetic oxide of iron is agitated with prussic acid, the black precipitate becomes blue; this insoluble compound is termed *Paris blue;* or, when it is mixed with white substances, — for instance, alumina, clay, starch, &c., — *Prussian* or *mineral blue.* Its constitution may be more readily imprinted on the memory by regarding it as prussiate of black oxide of iron. It consists, in fact, of protocyanide and sesquicyanide of iron, since a haloid salt and water are always formed when a hydrogen acid combines with a metallic oxide (§ 187). Both modes of consideration harmonize well with each other, for prussiate of protoxide of iron is the same as *cyanide* of iron + water,

$$Fe\,O + H\,Cy = Fe\,Cy + H\,O;$$

d prussiate of sesquioxide of iron is the same as
squicyanide of iron + water,

$$Fe_2\,O_3 + 3\,H\,Cy = Fe_2\,Cy_3 + 3\,H\,O.$$

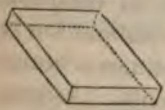
Prussian blue, on account of its splendid color, is not
nly an important article for staining wood, paper, &c.,
ut it is also one of the principal pigments for dyeing
oth, cotton, silk, &c. The color thus prepared is
lled, in dyeing establishments, *potassa blue*, to distin-
uish it from indigo blue. Prussian blue, although it
ntains prussic acid or cyanogen, is not poisonous.
imilar inconsistencies frequently occur in chemical
mbinations. Sometimes a poisonous combination is
rmed from innocuous bodies; and sometimes a harm-
ss compound from poisonous constituents. Accord-
gly, a correct inference cannot always be drawn as to
e medical effects of a compound merely from its con-
ituents.

Experiment. — Mix thoroughly together one dram of
ris blue (pure Prussian blue) and a quarter of a dram
oxalic acid, with some water; the color insoluble
water is rendered soluble by the oxalic acid, and a
ue liquid is obtained, which, if thickened with gum
rabic, may be used as a blue ink.

Experiment. — If you heat some Prussian blue upon
arcoal before the blow-pipe, an empyreumatic odor is
oduced; the cyanogen is consumed ($C_2\,N$ is con-
rted by the oxygen of the air into $2\,C\,O_2$ and N), and
u finally obtain only a brownish-red residue of ses-
ioxide of iron. Most of the cyanogen compounds
e decomposed in a similar manner by being heated
redness.

color of the mixture disap turbid, brownish-yellow liquid, w by filtration. What remains up ed sesquioxide of iron, which stronger potassa from the Pru

Fig. 142.



crystals are depo the clear yellow commonly called potassa, but in cl *rocyanide of pot* salt is formed as f

Prussian blue: iron with more cyanogen + ir
Potassa: oxygen and potassium,
Water: water,

Products: hydrated sesquioxide of iron, {
(Insoluble.)

The potassium of the potassa, as iron in the sesquicyanide of iron, fo tassium, which forms a double salt undecomposed protocyanide of ir the case, the prussic acid may be expelled from it by a stronger acid; this, in fact, does take place, for prussic acid is prepared from this salt by adding to it sulphuric or phosphoric acid and some water, and then distilling the mixture.

If blood and potassa lye are boiled together and evaporated to dryness, and the remaining mass is heated to redness, a yellow solution of ferrocyanide of potassium is obtained by the lixiviation of it with water. This salt, prussiate of potassa, must not be confounded with cyanide of potassium, a combination consisting of potassium and cyanogen alone, without iron, and which is a white salt and a *most deadly poison*. The ferrocyanide of potassium (the use of which term instead of prussiate of potassa will prevent the liability of mistaking one compound for the other) is not poisonous.

Ferrocyanide of potassium is prepared on a large scale in a manner similar to that above described. Blood, horn, leather, or other animal substances, are charred; this is best done by dry distillation, in order to obtain ammonia as a secondary product (§ 228); the charcoal thus obtained is then mixed with carbonate of potassa and iron, and the mixture fused at a red heat in a reverberatory furnace. In animal charcoal there is still contained nitrogen. This nitrogen, when heated to redness with a strong base, unites with carbon, forming cyanogen. The cyanogen then enters into combination with the potassium of the carbonate of potassa, which is reduced by means of the coal, forming cyanide of potassium. By dissolving the fused mass in water, a portion of the salt gives up its cyanogen to the iron, whereby ferrocyanide of potassium (and caustic potassa) is formed, which, after sufficient evaporation, crystallizes from the solution.

292. *Experiments with Ferrocyanide of Potassium.*

Experiment a. — By mixing a solution of ferrocyanide of potassium with sulphate of sesquioxide of iron a deep blue precipitate of Prussian blue is produced; for from

Ferrocyanide of potassium: protocyanide of iron + cyanide of potassium, and
Sulphate of sesquioxide of iron: ——— iron, oxygen, and sulphuric acid,

are formed { protocyanide of iron + sesquicyanide of iron (insoluble), and sulphate of potassa (soluble).

Experiment b. — Mix a solution of ferrocyanide of potassium with a solution of green vitriol; a light blue precipitate is formed (prussiate of protoxide of iron and potassa, or ferrocyanide of iron and potassium). Set aside one half of the solution, frequently stirring it; the light color of the precipitate gradually changes to a darker blue. This change takes place more rapidly by adding to the other portion a few drops of nitric acid, and heating the mixture. In both cases oxidation takes place, whereby a portion of the protoxide is converted into the oxide, so that prussiate of the magnetic oxide of iron or ferrocyanide of iron is formed. Both of the methods here given are employed in the preparation of *Prussian blue* on a large scale. In dyeing, the cloth is first steeped in a solution of iron, and then passed through a slightly acidified solution of ferrocyanide of potassium.

Experiment c. — Add a solution of ferrocyanide of potassium to a very diluted solution of blue vitriol; you obtain a purple red precipitate of *ferrocyanide of copper*. The copper gives up its oxygen and sulphuric acid to the potassium of the ferrocyanide of potassium, and sulphate of potassa remains dissolved in the liquid. This is the most accurate test for detecting the presence of copper in a liquid. Most of the basic elements, like copper in this instance, form double compounds with protocyanide of iron.

Experiment d. — Sprinkle some ferrocyanide of potassium upon a piece of red-hot sheet-iron, and quench it quickly in cold water; the iron becomes so hard as to resist the action of the file, a coating of steel having been formed on its surface by the carbon of the cyanogen. This simple process is especially adapted for imparting to agricultural implements a greater degree of hardness and durability.

293. *Red prussiate of potassa, or ferricyanide of potassium*, is distinguished from the yellow prussiate by containing sesquicyanide instead of protocyanide of iron. When added to salts of the protoxide of iron it forms a deep blue precipitate (but no precipitate is produced by it in the salts of the sesquioxide of iron); therefore, it is not only used for producing a blue color, but also as a reagent to distinguish the salts of the sesquioxide from those of the protoxide of iron.

Iron and Sulphur.

294. *Experiment.* — *Protosulphuret of Iron* (Fe S). — On adding some sulphuretted hydrogen water to a slightly acidified solution of green vitriol, no precipitate is produced; but if sulphuret of ammonium is added, a deep black precipitate is formed; this precipitate is *sulphuret of iron.*

295. *Experiment.* — *Sesquisulphuret of Iron.* — Twenty grains of sulphur and thirty grains of iron filings are thoroughly mixed and heated before the blow-pipe flame directed upon one part of the mass; this part attains a red heat, which rapidly pervades the whole mass. The yellowish-brown substance obtained is

ystematic Synopsis of the Compounds of Iron.

a.

buretted Iron.

ught-iron (iron + ½ per cent. of carbon).
iron (iron + 5 per cent. of carbon).
a mixture of both.

urets of Iron.

tret of iron, black.
uret of iron, yellow.
lphuret of iron, brownish-yellow, a mixture of both.

of Iron.

e of iron, black.
protoxide of iron, white.
de of iron, reddish-brown.
sesquioxide of iron, yellowish-brown.
xide of iron, black.
(lately discovered).

on.

Oxide.

Protoxide.
en.) Salts of the Sesquioxide.
(Brown.)
the protoxide of iron. Sulphate of the sesquioxide of iron.
" " "
" " " Nitrate " " "
" " "
" " Acetate " " "
Phosphate " " "
iron. "
Sesquichloride of iron.
otassium (yellow). Ferricyanide of potassium (red).
opper (red). Ferrocyanide of iron (blue).

MANGANESE (Mn).

At. Wt. = 345 — Sp. Gr. = 8.

xide or *Hyperoxide of Manganese* ($Mn\ O_2$).

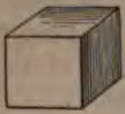
ments have already been performed
, which is chiefly obtained from the
nd from Thuringia; we use it espe-

sesquisulphuret of iron. Another method of preparing this substance, and of applying it to the evolution of sulphuretted hydrogen, has been described (§ 131). This combination also occurs native (magnetic pyrites).*

Experiment. — If you moisten protosulphuret of iron with water, and let it remain exposed to the air for some weeks, small green crystals will be found disseminated throughout the mass, both the iron and the sulphur having gradually attracted oxygen from the air. $Fe\,S$ is thus converted into $Fe\,O, S\,O_3$.

296. *Bisulphuret of Iron* ($Fe\,S_2$). — Iron containing twice as much sulphur as the protosulphuret occurs native in many ores, and frequently in hard coal, and is called *iron* pyrites or bisulphuret of iron. It has quite the appearance of brass, and usually occurs in cubic crystals. If heated in a retort, half of the sulphur distils over, and is collected, and a black sulphuret of iron remains behind; accordingly sulphur may be prepared from it. *Green vitriol* is prepared from this residue, by piling the latter in heaps, and leaving it for several months exposed to the air. The green vitriol thus formed is freed from earthy impurities by lixiviation and evaporation.

Fig. 143.



The salts of iron may be detected by their behaviour before the blow-pipe, by ammonia, tincture of galls, sulphuret of ammonium, and ferrocyanide of potassium.

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* The composition of magnetic pyrites generally corresponds to the formula $Fe_7\,S_8 = 5\,Fe\,S + Fe_2\,S_3$. — *Cours Élémentaire de Chimie par Regnault.*

Systematic Synopsis of the Compounds of Iron.

Iron.

Carburetted Iron.

a.) Wrought-iron (iron + ½ per cent. of carbon).
b.) Cast-iron (iron + 5 per cent. of carbon).
c.) Steel, a mixture of both.

Sulphurets of Iron.

a.) Sulphuret of iron,	black.
b.) Bisulphuret of iron,	yellow.
c.) Sesquisulphuret of iron,	brownish-yellow, a mixture of both.

Oxides of Iron.

a.) Protoxide of iron,	black.
Hydrated protoxide of iron,	white.
b.) Sesquioxide of iron,	reddish-brown.
Hydrated sesquioxide of iron,	yellowish-brown.
c.) Magnetic oxide of iron,	black.

d.) Ferric acid (lately discovered).

Salts of Iron.

a.) *Salts of the Oxide.*

Salts of the Protoxide. (Green.)	Salts of the Sesquioxide. (Brown.)
Sulphate of the protoxide of iron.	Sulphate of the sesquioxide of iron.
Nitrate " " "	Nitrate " " "
Carbonate " " "	
Acetate " " "	Acetate " " "
Phosphate " " "	Phosphate " " "

b). Haloid salts.

Protochloride of iron.	Sesquichloride of iron.
Ferrocyanide of potassium (yellow).	Ferricyanide of potassium (red).
Ferrocyanide of copper (red).	Ferrocyanide of iron (blue).

MANGANESE (Mn).

At. Wt. = 345 — Sp. Gr. = 8.

297. *Black Oxide or Hyperoxide of Manganese* ($Mn\,O_2$).

Several experiments have already been performed with this mineral, which is chiefly obtained from the Harz Mountains and from Thuringia; we use it especially for the preparation of oxygen and chlorine. It is one of the few combinations of oxygen termed *hyperoxides* or *superoxides;* so called because they contain an excess of oxygen, which they give out when heated to redness, or when heated with sulphuric acid. 100 ounces of black oxide of manganese, which contain 36 ounces of oxygen (2 atoms), yield at a moderate heat 9 ounces ($\frac{1}{2}$ atom), at an intense red heat 12 ounces ($\frac{2}{3}$ atom), on heating with sulphuric acid 18 ounces (1 atom), of oxygen. Therefore hyperoxide of manganese is excellently adapted *for combining other bodies with oxygen*, as was shown in the preparation of chlorine, when the oxygen of the hyperoxide of manganese oxidized the hydrogen of the muriatic acid, forming water, and thereby liberated the chlorine of the muriatic acid.

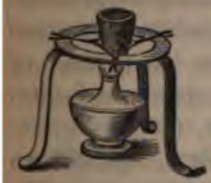
Glass-makers often add hyperoxide of manganese to the fused glass, to render the color of the black or dark-green bottle-glass yellow or orange, a shade which is generally preferred. In this case, also, an oxidation is effected by the hyperoxide of manganese. The dark color of the glass is owing to the protoxide of iron; this obtains oxygen from the hyperoxide of manganese, and becomes sesquioxide of iron, which colors the fused glass brown or yellow. If added in *small proportions* to white glass, it gives it a *violet* color, and in this way artificial amethysts are made.

Experiment. — Mix into a thin paste with water one fourth of a dram of finely pulverized hyperoxide of manganese, one dram of litharge, one of clay, and spread it over a tile. Put the latter between two glowing coals, or direct upon one part of it a strong blow-pipe flame; the mass melts, and forms on cooling a brilliant black coating, or, if less manganese be used, a brown coating. This is the method by which potters prepare their black or brown glaze.

298. *Manganese* (Mn). — By intensely heating the hyperoxide of manganese with charcoal, all its oxygen may be expelled, and a grayish-white brittle mass (Mn) is obtained, much more difficult of fusion than even iron.

Other Combinations of Manganese.

Fig. 144.



299. *Experiment.* — Mix in a porcelain crucible a quarter of an ounce of hyperoxide of manganese with one eighth of an ounce of sulphuric acid, and expose the mixture to a gentle heat for fifteen minutes, and then to a strong heat for an hour. After cooling, boil the black mass in water, and evaporate the solution to dryness, constantly stirring it when nearly dry; the reddish-white powder is *sulphate of protoxide of manganese* ($MnO, SO_3 + 4HO$). Half of the oxygen escaped during the heating, and protoxide of manganese (MnO) remained behind, which, being a salt-base, combined with the sulphuric acid. *Muriate of protoxide of manganese*, or protochloride of manganese ($MnCl$), was formed during the preparation of chlorine (§ 150), and remained in the flask, having obtained a yellow color owing to the presence of chloride of iron. Most of the salts of the protoxide of manganese have a reddish color.

300. Dissolve a portion of the *sulphate of protoxide of manganese*, and use the solution for the three following experiments.

Experiment a. — On exposure to the air, the solution acquires a dark-brown color, and after a time deposits a powder of the same color, just as occurred in the solution of the sulphate of protoxide of iron. The *protoxide of manganese* attracts oxygen from the air, and is converted into hydrated sesquioxide of manganese, from which a part separates, sufficient acid not being present to retain all the sesquioxide in solution.

Experiment b. — If some ammonia or potassa is added to another portion of the solution, the stronger bases will overpower the sulphuric acid, and *hydrated protoxide of manganese* ($MnO + HO$) will separate as a white precipitate. On filtering and drying, it will become converted into dark-brown *hydrate of sesquioxide of manganese* ($Mn_2O_3 + 3HO$), precisely as occurred with the hydrated sesquioxide of iron. If a piece of linen, immersed in the solution, is dried, and then passed through a solution of potassa, the precipitate will adhere firmly to the fibres of the cloth, and will acquire, on exposure to the air, a fine dark-brown color, called by dyers *manganese-brown*.

Experiment c. — Add some sulphuretted hydrogen to a third portion of the solution; no change takes place until some ammonia is added, when a flesh-colored precipitate is produced, consisting of *manganese* and *sulphur* (MnS). In this manner, the presence of manganese in a solution may be ascertained, for manganese is the only metal which, on combining with sulphur, yields a metallic sulphuret of a pink color. This experiment also affords another example of double elective affinity causing a decomposition which could not be effected by simple elective affinity.

301. *Acids of Manganese.* — Manganese is characterized by combining with still more oxygen than is already contained in the hyperoxide.

Experiment. — Mix intimately together in a mortar one dram of hyperoxide of manganese and one dram of caustic potassa; put the mixture in a porcelain crucible, and heat it strongly for half an hour. When cold, add some water to the black mass; you will obtain a green solution, which becomes clear by settling in a test-tube. This green color is owing to the formation of a salt, which is called *manganate of potassa*, or *chameleon mineral*. By the ignition with potassa, the hyperoxide of manganese is disposed to receive an additional atom of oxygen from the air, and $Mn\,O_2$ is converted into $Mn\,O_3$, which latter compound comports itself as an acid; that is, it combines with the base present, forming a salt ($K\,O,\ Mn\,O_3$).

Experiment. — Pour half of the green solution into a wine-glass, dilute it with water, and leave it in repose; the green color soon begins to change, passing through bottle-green and violet to a crimson-red, a brown powder (hyperoxide of manganese) being at the same time deposited. This apparently voluntary change is occasioned by the carbonic acid of the air, which combines with a portion of the potassa and expels the manganic acid. The manganic acid ($Mn\,O_3$), however, on being deprived of its base, immediately separates into two parts, one of which contains *less* oxygen (hyperoxide of manganese, $Mn\,O_2$), and the other *more* oxygen (permanganic acid, $Mn_2\,O_7$); $3\,Mn\,O_3$ is converted into $Mn\,O_2$ and $Mn_2\,O_7$. The red color belongs to the *permanganic* acid, which remains in solution, combined with a portion of the *potassa*.

Experiment. — Add some drops of sulphuric acid to another portion of the green solution, when the change of color from green to red, that is, the conversion of manganate into permanganate of potassa, will take place instantaneously.

The most remarkable characteristic of these acids is *the facility with which they surrender that portion of their oxygen which stamps them as acids.* Even a piece of wood, paper, or any other organic substance, thrown into the green or red solutions, decomposes them and removes their color, and for this reason they should never be filtered through paper. From its singular changes of color, manganate of potassa has received the name of *chameleon mineral.*

302. Manganese forms with oxygen alone a great variety of combinations.

345 lbs. of manganese or 1 at. Mn	form with " "	100 lbs. of oxygen 1 at. O	Protoxide of manganese, = $Mn\,O$.
345 lbs. of manganese or 1 at. Mn	form with " "	150 lbs. of oxygen 1½ at. O	Sesquioxide of manganese, = $Mn_2\,O_3$.
345 lbs. of manganese or 1 at. Mn	form with " "	200 lbs. of oxygen 2 at. O	Hyperoxide of manganese, = $Mn\,O_2$.
345 lbs. of manganese or 1 at. Mn	form with " "	300 lbs. of oxygen 3 at. O	Manganic acid, = $Mn\,O_3$.
345 lbs. of manganese or 1 at. Mn	form with " "	350 lbs. of oxygen 3½ at. O	Permanganic acid, = $Mn_2\,O_7$.

It is, moreover, hereby rendered very obvious, that it is the *quantity* of the oxygen which makes one and the same element sometimes a *base*, sometimes an *acid.* Some idea may be formed of the great army of salts which manganese alone, in virtue of this double character, can call into the field, when we reflect that it not only combines with all the acids, forming protoxides and sesquioxides, but also with all the bases, forming manganates and permanganates.

COBALT (Co) AND NICKEL (Ni).

At. Wt. = 368. — Sp. Gr. = 8.5. At. Wt. = 369. — Sp. Gr. = 9.

303. During the Middle Ages, when the miner held intercourse with earth-spirits and goblins in the solitary

depths of his mines, ores were occasionally found, particularly in the mines of Schneeberg, in Saxony, resembling, in brilliancy and solidity, the finest silver ores, which, however, yielded in the smelting furnaces no silver, but crumbled away to a gray ashes, a disagreeable odor of garlic being at the same time emitted. In accordance with the superstitious notions of those times, the miner attributed the disappearance of the supposed silver to the malicious jests of the earth-spirits, and contemptuously rejected these ores, which he baptized by their names,—cobalt and nickel. But now they are held in high estimation, cobalt being used for imparting a beautiful blue color to glass and porcelain, and nickel for giving to brass the appearance of silver. As these metals are melted only with great difficulty, the heat of the old furnaces was not sufficient to fuse them. The odor of garlic was occasioned by the arsenic, which always accompanies the ores of cobalt and nickel.

304. *Smalt, Azure, or Cobalt-blue.*—The ores (white cobalt, cobalt pyrites, cobalt glance, &c.) containing arsenical cobalt and nickel are now worked in the following manner. The stamped ores are first roasted in a reverberatory furnace, to expel any arsenic that may be present, and to convert the cobalt into oxide of cobalt; then it is mixed with sand and carbonate of potassa, and the mixture fused in clay crucibles. Thus a glass is produced, in which the oxide of cobalt dissolves, imparting to it a deep blue color; but the arsenical nickel, together with some silver and bismuth present, collects at the bottom of the crucible as a fused metallic lump (*speiss*). The melted blue glass is rendered brittle and friable by pouring it into cold water, after which it is ground to an impalpable powder, and elutriated. It is much used, under the name of *smalt*

and *azure*, not only as a vitrifiable pigment for glass, porcelain, and pottery, but for coloring paper, and also in washing, for giving a blue tint to linen and muslin.

305. *White Copper, or German Silver.* — The speiss, which remains after the fusion of the cobalt ore, is now generally used in the preparation of *German silver.* The arsenic being first expelled, the bismuth, silver, and nickel are melted with from four to five times as much brass (copper and zinc), whereby a metallic mixture (an alloy) of a silvery-white color, beautiful brilliancy, and great malleability, is obtained. This alloy is extensively used, as a substitute for silver, in the manufacture of a great variety of articles, not only of convenience, but of luxury.

306. As pure metals, *cobalt* and *nickel* have a great similarity to iron, both in their external appearance and in their combinations; but they are nobler metals, that is, they do not attract oxygen with such avidity, and they do not rust so readily as iron. The three metals, iron, cobalt, and nickel, constitute, as has been already mentioned, the *magnetic trio;* they alone, of all the metals, are attracted by the magnet. It is, moreover, remarkable, that just these three metals always occur in meteorites, which occasionally fall to the earth, we know not whence, in a glowing state (meteoric iron, meteoric stones).

The *fly-poison* of the apothecaries is also frequently called cobalt, but most inappropriately, as it does not contain a particle of cobalt; it is metallic arsenic.

307. Both these metals, like iron, form with *oxygen* a protoxide and a sesquioxide.

Protoxide of cobalt ($Co\,O$) is of an ash-gray color, and its *hydrate* is pink; *sesquioxide of cobalt* ($Co_2\,O_3$) is black. These oxides are frequently employed in *painting* on porcelain and glass.

Protoxide of nickel ($Ni\,O$) is of a greenish-gray, and its *hydrate* of a beautiful apple-green color; *sesquioxide of nickel* ($Ni_2\,O_3$) is black. Chrysoprase, known as an ornamental stone, is quartz, colored green by protoxide of nickel.

308. The *salts of protoxide of cobalt* are of a pink color. A solution of the *nitrate of protoxide of cobalt* is often used in blow-pipe experiments, especially for the detection of alumina (§ 262); a solution of *protochloride of cobalt* is employed as a sympathetic ink, as it possesses the property of becoming blue by evaporating the water, and again pink on absorbing water. Cobalt forms, with phosphoric and arsenious acids, red insoluble compounds, which are now employed as vitrifiable pigments in glass and porcelain painting. The *salts of protoxide of nickel* have a light-green color.

The salts of cobalt and nickel, like those of iron, are not precipitated by sulphuretted hydrogen, but they are by sulphuret of ammonium, as black *sulphuret of cobalt* and *nickel.*

ZINC (Zn).

At. Wt. = 407.—Sp. Gr. = 6.8.

309. Not very long ago, zinc was hardly used except for making brass and pinchbeck; but since the art of rolling it out into plates, of forging it, and of drawing it out into wire, has been acquired, it is used also for the manufacture of many articles which were formerly made of lead, copper, and iron; for instance, for making nails, gasometers, gas-pipes, gutters, and for covering roofs of houses, for lining refrigerators, &c., as it is harder, and yet lighter, than lead, cheaper than copper, and less liable than iron to be destroyed by air and water.

It usually occurs in commerce in the form of sheets, which are so brittle, that they may be broken by the hammer into small pieces; the fresh fracture exhibits a *hackly** crystalline structure, and a bluish-white color.

310. *Experiments with Zinc.*

Experiment a.—When polished zinc remains exposed to the air for some time, it loses its lustre, and is covered with a gray film. This film consists of zinc combined with a small quantity of oxygen, and is called *suboxide* of zinc.

Experiment b.—If a piece of polished sheet zinc be alternately exposed to the action of water and of air, it will become gradually covered with a white film; it rusts like iron, but the rust of zinc has a white color. In iron the oxidation proceeds rapidly towards the interior, but not in zinc, or only very slowly; therefore articles made of zinc, when exposed to the wind and weather, last much better than those made of iron, and for this reason, also, iron articles are frequently coated with zinc (galvanized iron). Iron-rust is hydrated sesquioxide of iron, zinc-rust is hydrated oxide of zinc. Zinc attracts not only oxygen, but also some carbonic acid, from the air, and this may be recognized by the effervescence which follows when some acid is dropped upon the rusted zinc; consequently, the white film is a double compound of hydrated oxide of zinc with carbonate of oxide of zinc (*basic carbonate of zinc*).

Experiment c.—Hold a piece of zinc by means of a pair of tongs or pincers in the alcohol-flame, until it hisses if you touch it with a piece of moist wood; if you now quickly hammer it upon a stone or anvil pre-

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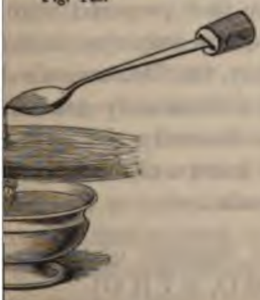
* "*Hackly fracture;* when the elevations are sharp or jagged, as in broken iron."—Dana's *Manual of Mineralogy.*

ated, it does not break, but spreads out like
a thin, coherent sheet. Zinc has the singular
f being ductile from 100° C. *to* 150° C., but
bove this temperature it is brittle. Ever since
n known that zinc is thus affected by heat, it
found easy to overcome the difficulties which
opposed the conversion of this metal (which
t when cold) into sheets and wire.

nent d. — Zinc, when heated to about 400° C.,
may easily be seen by holding a small piece
an iron spoon over an alcohol flame. In this
ay film of suboxide is likewise formed; but
a time assumes a yellow color, and is con-
o oxide (ZnO). On cooling, the yellow color
white; the oxide of zinc belongs to those
s which present a color in the heat different
color at the ordinary temperature.

nent e. — In chemical experiments, especially
olution of hydrogen, it is very convenient to
in the form of small grains (granulated). It
is very easily obtained in this state, by pouring the melted metal through a moistened broom, gently shaking it while it is held over a basin of water. In this way the other easily fusible metals also, such as lead, tin, bismuth, &c., may be
l into smaller parts, and with much more fa-
n by filing or cutting.

Fig. 145.



nent f. — At a still stronger heat, zinc *evapo-*

rates, and *burns* at the same time, with a bluish flame. In this experiment, the spoon containing the zinc must be placed on red-hot coals, that it may become hotter than by the spirit-lamp. A beautiful appearance is presented, even on a small scale, by heating a piece of zinc upon charcoal, before the blow-pipe; the metal is soon converted into a loose, spongy mass of oxide, and during the combustion, blue flames burst forth from the oxidized coating. The oxide is *not volatile*, for if it were, nothing at all would remain behind. The flame is caused by the burning fumes of zinc; the substance formed by the combustion is oxide of zinc. This is called *oxide prepared in the dry way*, or *flowers of zinc*, and it may be freed from any admixture of metallic particles by elutriation. Zinc has only this *one* degree of oxidation.

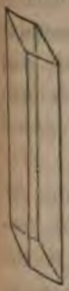
Zinc and Acids.

311. All *diluted acids* dissolve zinc with ease, with the evolution of hydrogen, and form with the oxide produced *salts of zinc*. The hydrogen liberated in this way is much purer than that prepared with iron; on this account, zinc is generally employed in the preparation of hydrogen, namely, for Dobereiner's hydrogen-lamp, balloons, &c. If, as is usually done, diluted sulphuric acid is taken for dissolving the zinc, we obtain on evaporation the best known of the salts of zinc, the sulphate of the oxide of zinc.

312. *White Vitriol, or Sulphate of Oxide of Zinc* ($Zn O, S O_3 + 7 H O$).

This salt crystallizes in colorless, rhomboidal prisms, which contain nearly half their weight of water of crystallization. Sulphate of the oxide of zinc, called also white vitriol, is easily soluble in water, and is often employed as a cooling application, particularly in inflammation of the eyes. Tolerably large quantities of this salt may be prepared without much trouble, by evaporating the waste liquids left after generating hydrogen from zinc and sulphuric acid. The black substance which deposits from the solution of zinc is for the most part charcoal, a little of which always unites with zinc on the smelting of it from its ores. As it is not soluble in acids, it must remain behind on dissolving the metal.

Fig. 146.



All the salts of zinc are *poisonous*, and excite, when introduced into the stomach, violent vomiting; milk, white of eggs, and coffee are employed as antidotes.

Experiments with White Vitriol.

a.) Prepare a solution of white vitriol, and add to it *ammonia* or *potassa*. A white precipitate of *hydrated oxide of zinc* is formed, which dissolves again in an excess of the alkali.

b.) *Sulphuret of ammonium;* here also a white precipitate is produced; this is *sulphuret of zinc*. This behaviour of zinc is taken advantage of to distinguish and to separate it from other metals. Sulphuret of zinc also occurs native, but then it has a red or a brown color, and is called *zinc blende*. From this ore, by roasting, weathering, and lixiviation, white vitriol is prepared, precisely in the same manner as green vitriol is obtained from sulphuret of iron.

c.) *Carbonate of soda; carbonate of the hydrated oxide of zinc* is obtained likewise in the form of a white precipitate. If this is dried, after having been

313. Carbonate of zinc occurs als
abundantly, in Silesia, Westphalia, a
the most important zinc ore, and fro
zinc is always prepared in the above-
The miner calls this ore *calamine*.

314. *Preparation of Zinc.* — In orde
calamine into metallic zinc, the carb
ygen must be expelled. The first is
same way as with carbonate of lime
furnaces, and the latter in the same
iron ores, by heating to redness with ch
process of reduction cannot be condu
naces, for in them the reduced zinc
and burn up in the air, forming agai
so that from oxide of zinc in the fur
only obtain oxide of zinc in the air. I
cess of *distillation* than of melting that
take. Clay cylinders or muffles are e
ducting the distillati
these are ranged in c

Fig. 147.

is again to be melted and cast into sheets. The zinc of commerce always contains an admixture of small quantities of iron and lead. If the amount of lead is more than one and a half per cent., then the zinc remains brittle, even when heated, and cannot be rolled out into sheets.

CADMIUM (Cd).

At. Wt.=697.—Sp. Gr.=8.6.

315. *Cadmium* is a rare metal, and may be regarded as the twin brother of zinc, in the ores of which it is found in small quantities. It is chiefly distinguished from zinc by its malleability when cold, and by being precipitated from its solution by sulphuretted hydrogen as *yellow sulphuret of cadmium*. As already mentioned, this reagent gives no precipitate with the salts of zinc, but the latter is thrown down by sulphuret of ammonium, as *white sulphuret of zinc*.

TIN, STANNUM (Sn).

At. Wt. = 756.—Sp. Gr. = 7.2.

316. *Tin* is one of the few metals which were known in the most ancient times. It becomes fluid at a very moderate heat, at 230° C., and in many countries its ores are found in the sand with which the surface of the soil is covered; therefore it was easily obtained and easily smelted. Formerly it was fetched principally from the British Islands, which were, therefore, called also Tin Islands, and even at the present time they, together with Malacca in the East Indies, furnish the purest tin. The properties which especially characterize tin, and render it a very valuable metal, are its beautiful lustre, and its great softness and flexibility,—its slight

affinity for oxygen, in consequence of which it long retains its brightness in the air and in water, — its easy fusibility, which renders it peculiarly well adapted for casting, and for coating other metals (*tinning*). It has, indeed, lost much of its earlier importance as a material for making many vessels of domestic use, such as dishes, cans, &c., since such articles are now handsomely and cheaply manufactured from glass and porcelain. But it is now applied in the arts and trades in a variety of ways not formerly in use. In the older works on chemistry, it is called *Jupiter*, and has the symbol ♃.

317. *Experiments with Tin.*

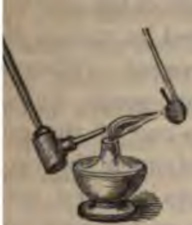
Experiment. — Heat a piece of tin upon charcoal before the blow-pipe; it will soon become covered with a powder, of a yellow color when hot, but white when cold; this is *peroxide of tin*, a combination of one atom of tin with two atoms of oxygen ($Sn O_2$). Peroxide of tin thus obtained is *not* soluble in *any acid*, and cannot be fused by the strongest heat. It is so delicate a powder, that it is often used for polishing glass and metals.

Tin also occurs native as an insoluble oxide, either crystallized (crystals of tin ore), or scattered through various kinds of rocks (tin-stone of Saxony and Bohemia), or, finally, as an ingredient of the sand or *débris* of low grounds in many countries (wood-tin in England). Oxide of tin is the only ore from which tin is largely extracted; its most common admixtures are iron and arsenic.

Experiment. — Place two grains of tin and eight grains of lead on charcoal, and heat them before the blow-pipe; they melt and combine most intimately with each other; an alloy of tin and lead is obtained. If this is heated to redness, the oxidation proceeds so

y, that the mass takes on a lively motion, and con-
to glow even when it is removed from the fire. In
this manner the potter prepares
the porcelain-like glaze for earthen
baking-pans, and for Delft
ware. Add some powdered borax
to this mixture of oxides of
lead and tin, and form with it a
bead upon platinum wire; the
bead is not transparent, but, owing
to the presence of the infusible
peroxide of tin, is opaque, and
looks like porcelain (enamel).

Fig. 148.



. *Alloys* of tin and lead are generally used by
rs in metal, under the name of *solder*, for join-
netals together (soft soldering). Solder is to
man what glue is to the carpenter. An alloy of
arts of tin and one part of lead is the most easily
e, and is called *fine solder*. Another alloy, used
soldering of coarser articles, such as gutters, is
sed of two parts of lead and one part of tin, and
ed *coarse solder;* it is so thick that it does not
l of itself, but must be applied by smearing. For
ing those metallic articles which are to be subject-
a stronger heat, brass, or some other alloy of diffi-
sibility, is made use of (*hard solder or brazing*).
ne lead is added even to the tin of which the tin-
nakes his articles, because pure tin is somewhat
, and does not adapt itself well to the moulds.
uantity of lead which can be added to tin is in
countries regulated by law ($\frac{1}{5}$ to $\frac{1}{6}$). Such an
is called *proof tin*, to distinguish it from refined
in tin, which is tin in its greatest purity. If an
such as is used in cookery, be poured on proof tin,

the tin only is dissolved; tin has, accordingly, the power of protecting lead from the attacks of acids.

Tin and Muriatic Acid.

319. The most important solvent of tin is *muriatic acid;* the two most important salts of tin, protochloride and perchloride of tin, are prepared by means of it.

Protochloride of Tin.—*Experiment.*— Place in two porcelain bowls or earthen pots some tinfoil, and then add some muriatic acid to one of the portions. After some hours pour this acid upon the tin of the second vessel, and then again into the first vessel, repeating the process so that the metal may come in contact for some days alternately with the air and the muriatic acid. Protoxide of tin is formed by the oxygen of the air; it is dissolved by the acid. We thus obtain a solution of the *muriate of protoxide of tin*, or *protochloride of tin*, from which, on evaporation and cooling, colorless rhomboidal prisms are deposited. In commerce this salt is called *salt of tin.* It possesses, in common with the salts of protoxide of iron, the property of attracting with great avidity still more oxygen from the air, and changing into a peroxide salt. Thus is explained why the salt of tin, which has been for some time exposed to the air, no longer presents a clear, but a milky, solution. To obtain a clear solution, muriatic acid must be added, which combines with the precipitated peroxide of tin.

320. *Protoxide of Tin* (SnO).—*Experiment.*— Pour some ammonia upon a solution of salt of tin; the white precipitate which is formed is hydrated *protoxide of tin.* By boiling the solution, the combination of the protoxide and water is destroyed, and an anhydrous protoxide of tin is formed, which has a dark-green col-

or, and must be quickly washed with boiled water and dried, as it likewise attracts more oxygen from the air. If you heat the dried protoxide before the blow-pipe, it burns with great briskness, like tinder, forming peroxide of tin.

321. *Perchloride of Tin* ($Sn\,Cl_2$).—*Experiment.*—Add chlorine water to a solution of salt of tin, until the odor of chlorine is no longer destroyed. $Sn\,Cl$ is thereby converted into $Sn\,Cl_2$, or *perchloride of tin.* This combination can also be obtained by boiling a solution of salt of tin in a mixture of muriatic acid and nitric acid, or by dissolving tin in aqua regia. The dyers call this liquid permuriate of tin, tin mordant, or red spirits. By the addition of ammonia *peroxide of tin* is obtained, which is distinguished from that formed at § 317 by its dissolving *very easily* in acids.

Protoxide and peroxide of tin dissolve also in potassa lye, and comport themselves, like alumina (§ 260), as acids towards strong bases.

322. *Experiment.*—If a few drops of a solution of gold are added to a very diluted solution of protochloride of tin, a purple-red precipitate is formed (but not in a solution of perchloride of tin), which is called *purple of Cassius*, or *gold purple*, and is one of the most important vitrifiable pigments, because it produces, when fused into glass or porcelain, the most superb purple-red color. Solution of gold is a good test for the salts of the protoxide of tin.

323. *Experiment.*—Mix a decoction of Brazil-wood with protochloride or perchloride of tin; the yellowish-red color of the liquid is converted into a beautiful crimson-red. Similar advantageous changes of color are also effected by these salts in other coloring matters, and on this account they are very frequently used as so-called *mordants in dyeing* and calico-printing.

Tin and Nitric Acid.

324. *Experiment.* — Heat some grains of tin with nitric acid in a test-tube; the tin is converted, under a brisk evolution of yellow fumes, into a white powder, *peroxide* of tin. The nitric acid will perhaps convert the tin into an oxide, but it *cannot* combine with the oxide produced. The peroxide of tin thus obtained combines indeed with other acids, but *not so completely* as that obtained according to § 321; that prepared by heating does not *at all* unite with them, as has been already stated (§ 317). Peroxide of tin accordingly occurs in three isomeric states; namely, the insoluble, the very easily soluble, and the difficultly soluble, in acids.

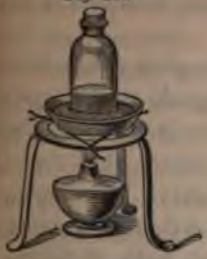
Tin and Sulphur.

325. *Experiment.* — Sulphuretted hydrogen water produces, in a solution of protochloride of tin, a reddish-brown precipitate of *protosulphuret of tin* ($Sn\ S$), and in a solution of perchloride of tin a yellow precipitate of *bisulphuret of tin* ($Sn\ S_2$). It is obvious, that in the first case one atom of chlorine is replaced by one atom of sulphur, and in the latter case two atoms of chlorine by two atoms of sulphur.

Protosulphuret of Tin ($Sn\ S$). — *Experiment.* — Both these metallic sulphurets may be prepared in the dry way. Envelop 12 grains of flowers of sulphur in a piece of tinfoil, weighing 24 grains, then roll up the package so that it may be introduced into a test-tube, and heat it; half of the sulphur burns up, but the other half, under a lively glowing, combines with the tin, forming a brownish-black mass of a metallic lustre ($Sn\ S$). If you sprinkle the glass, while still hot, with water, it is rendered friable, and can easily be separated from the fused protosulphuret of tin. The weight of the latter amounts to nearly thirty grains.

Bisulphuret of Tin ($Sn\,S_2$). — *Experiment.* — Pulverize the thirty grains of protosulphuret of tin thus obtained, and mix the powder intimately with six grains of sulphur and twelve grains of sal ammoniac; put the mixture into a thin-bottomed glass flask of an ounce capacity, and heat it for an hour and a half in a sand-bath. You obtain bisulphuret of tin, but in this case as a mass having a golden lustre, and to which the name *aurum musivum* or *mosaic gold* has been given. It may be used for giving a gold-like coating to wood, gypsum, clay, &c. (*bronzing*). The sal ammoniac is found again as a sublimate in the upper portion of the flask; it promotes the formation of the beautiful gold color, without itself undergoing or producing any chemical change.

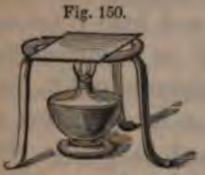
Fig. 149.



326. *Preparation of Tin.* — Tin is prepared in smelting-houses, in a very simple manner, from tin-stone (peroxide of tin). The finely stamped ore is first roasted, by which process the arsenic is volatilized and the iron oxidized. Then it is washed or elutriated with water, whereby the lighter particles of stone (the *gangue*), and to a great extent also the oxide of iron, are washed away. Finally, it is fused with charcoal in a blowing-furnace, and carbonic oxide gas and metallic tin are obtained, the latter of which flows off below. The Saxony tin is usually cast in thin sheets, and the English tin in slender bars. Most of the tin of commerce contains traces of arsenic and other metals. A bar of

tin emits a grating sound on being bent, and by repeating the operation several times in succession, it becomes very hot; the reason is, that the tin, on hardening, assumes a crystalline texture, and these crystalline particles are displaced by the bending, and rub against each other. These crystals may be very beautifully produced upon tinned-iron sheets.

Fig. 150.



Experiment. — Heat a piece of tin plate (tinned-iron plate) upon a tripod, over a spirit-lamp, till the tin is melted; then quench it with water, that the tin may harden quickly. The surface of the plate has a dull gray aspect, for it is covered with a film of oxide; but the most beautiful crystalline figures will very soon appear upon it by rubbing it alternately with balls of paper, one of which is moistened with diluted aqua regia, and the other with potassa lye. Both these liquids dissolve the coating of oxide, and lay bare the pure metallic tin surface (*moiré métallique*).

327. *Tinning.* — *Experiment.* — The method of coating copper or brass with tin has already been described (§ 229). This may be done also in the moist way, by heating to their boiling point finely divided tinfoil, or tin scrapings, in a pot with cream of tartar and water, and then boiling for half an hour in this liquid some brightly polished copper or brass articles; as, for instance, cents or brass nails. The free acid of the cream of tartar effects a solution of some of the tin, and on longer boiling this tin will again separate as a metal upon the more electro-positive copper or brass, as in § 284. In this manner pins are tinned, or whitened.

Experiment. — Let some vinegar stand over night in a vessel of tin plate, and then test it with a solution of gold; the purplish color which forms indicates that even the weak vinegar can dissolve tin. Tin is not indeed so poisonous as lead or copper, but yet it is injurious to health; therefore, acid food and drinks should not be allowed to stand for any length of time in tin or in tinned vessels.

Spurious silver-leaf is made of an alloy of tin and zinc, which is hammered out into extremely thin leaves.

URANIUM (U).

At. Wt. = 750.—Sp. Gr. = ?

328. *Uranium* is one of the rarer metals, and occurs in combination with oxygen in a black mineral called pitch-blende, found in Saxony. From it is prepared the uranate of ammonia, a beautiful yellow powder, known in commerce under the name of *oxide of uranium.* At a white heat it is reduced to black protoxide, and yields a very permanent black pigment for painting on porcelain. The yellowish-green (may-green) glass, now so popular, likewise owes its color to the oxide of uranium.

The following metals, *Cerium, Lanthanium, and Didymium*, are mentioned here only by name, as chemical rarities.

RETROSPECT OF THE FIRST GROUP OF HEAVY METALS.

1. The metals hitherto considered possess the property of decomposing water, when they are heated to redness, or with the presence of an acid (water-decom-

they most frequently occur as
combined with *oxygen.*

4. The specific gravity of th
to 8.8.

5. Iron, manganese, zinc, cob
precipitated as sulphurets from t
sulphuretted hydrogen, but only b
nium (all the other heavy metals
of the solutions into sulphurets)
available in analytical chemist
means of separating the above-na
from the other (electro-negative)

SECOND GROUP OF HE

LEAD, PLUMBUM

At. Wt. = 1294. — Sp. G

329. Next to iron, *lead* is the
and the cheapest metal; it is, a

ately when the lead enters the system; it is often only after the lapse of years that they appear (lead colic). It is, for this reason, classed among the *slow poisons*. Perhaps, also, this was the reason why it was formerly compared with the god of time, and received the name of Saturn and the sign ♄. The external properties of lead, its lustre, its easy fusibility, its softness and pliability, its high specific gravity, &c., are well known; therefore we shall proceed at once to the consideration of its internal or chemical character.

Experiments with Lead.

330. *Experiment.* — Pour into one glass distilled water, into another spring-water, and place in each a piece of lead; the distilled water soon becomes turbid, and reacts basically, but not so the spring-water. Pure water readily attacks lead, and converts it into hydrated oxide of lead; in spring-water, on the contrary, there is formed in time, by the sulphates almost always present in it, some insoluble sulphate of lead, which forms a firm coating upon the metallic lead. This explains the harmlessness of leaden pumps, which, in many countries, are quite generally used instead of wooden pumps.

331. *Experiment.* — If lead is heated before the blowpipe in the exterior flame, it melts at about 320° C., and is thereby coated with a gray film; indeed, it is finally entirely converted into a gray powder. This may be regarded either as suboxide of lead, or as a mixture of oxide of lead with metallic lead. By continued blowing, this gray color is changed to yellow; the yellow body is *protoxide of lead* ($Pb\,O$). At a stronger heat the oxide melts, and solidifies on cooling into a reddish-yellow mass, composed of brilliant scales, the well-

known *litharge*. By directing upon it the *inner* blowpipe flame, metallic lead will again be obtained. This easy reducibleness, which is peculiar to almost all salts of lead, together with the *incrustation of yellow oxide, deposited upon the charcoal*, is a certain test for the presence of lead.

Oxide of lead contains, for every 100 pounds of lead, 8 pounds of oxygen, or one atom of lead (1294) and one atom of oxygen (100); lead, consequently, is one of those chemically feeble bodies which have a very high atomic weight, since 1294 pounds of it is able to accomplish only as much as 350 pounds of iron, or 407 pounds of zinc. Protoxide of lead in the form of *litharge* has a very great application in the arts and trades. How lead-glass (flint-glass), lead-glaze, and sugar of lead are prepared from it, has already been described; the manufacturing chemist likewise prepares from it red lead, white lead, and other lead colors, and lead salts; the apothecary compounds insoluble soap (lead plaster), by boiling it with olive-oil; the cabinet-maker makes a varnish that dries rapidly, by boiling it with linseed oil, &c. The English litharge is esteemed the purest; that of Saxony and Goslar always contains small quantities of oxides of copper and iron, perhaps also a little silver. The preparation of it on a large scale will be described under silver. By melting litharge in a Hessian crucible, a brownish-yellow transparent glass is obtained on cooling; this consists of oxide of lead combined with some silicic acid. The silicic acid came from the crucible.

332. *Red Oxide of Lead.* — *Experiment.* — Heat in a ladle one dram of litharge and a quarter of a dram of chlorate of potassa; the yellowish mixture smoulders to a red powder, which must be well washed with

water. The same thing happens on heating the litharge for a day, but not to the melting point, and at the same time frequently stirring it. In both cases the litharge receives one third more of oxygen; in the former case from the chloric acid, in the second case from the air; and is thereby converted into Pb_3O_4; this compound is called *red oxide of lead*, or *minium*, and is much used as a scarlet pigment.

333. *Peroxide of Lead* (PbO_2). — *Experiment.* — If you heat some red lead gently in nitric acid for a few minutes, it is resolved into an oxide, which dissolves, and into *hyperoxide* (PbO_2), which remains undissolved as a dark-brown powder. Lead is one of the few metals which combine with oxygen, forming hyperoxides.

Lead and Acids.

334. The best solvent of lead is nitric acid. Sulphuric, phosphoric, and muriatic acids *cannot* dissolve lead, because they form with it insoluble, or very difficultly soluble salts. As protoxide of lead is easily made, the most advantageous method of preparing the salts of lead is by dissolving the protoxide in acids, because that portion of the acid is thereby saved which would otherwise have been required for the conversion of the lead into the oxide of lead.

Nitrate of Lead (PbO, NO_5) has already been prepared in two ways (§ 160).

335. *Sulphate of Lead* (PbO, SO_3) (§ 173).—This salt is easily formed by simple or double elective affinity, when sulphuric acid or sulphate of soda is added to a solution of lead. Even in a solution of lead more than a thousand times diluted, a white turbidness is produced, since the sulphate of lead is an entirely in-

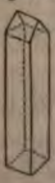
soluble salt; we have, accordingly, in sulphuric acid, a very delicate test for salts of lead. This salt is obtained in great quantities in print-works, as a secondary product in the preparation of the acetate of alumina (*alum mordant*) from sugar of lead and alum (§ 262).

336. *Chloride of Lead* (Pb, Cl). — *Experiment.* — Heat to boiling one dram of litharge, with half an ounce of muriatic acid and half an ounce of water, and decant the clear liquid from the sediment into a glass vessel; you obtain, on cooling, lustrous white acicular crystals of chloride of lead (horn-lead). This salt is but very sparingly soluble in water.

Experiment. — If two grains of litharge and fifteen grains of sal ammoniac are fused together in an iron spoon, there is obtained a combination of a small quantity of chloride of lead, with a large proportion of oxide of lead, in the form of a brilliant, yellow, laminated mass, which when triturated yields a handsome yellow powder. This powder is used by painters under the name of *Cassel* or *mineral yellow*.

337. *Acetate of Oxide of Lead* ($PbO, \overline{A} + 3\,HO$), combined with one seventh of its weight of water of crystallization, forms the most important soluble salt of lead, *sugar of lead* (§ 198), which commonly crystallizes in four-sided prisms. On exposure to the air, some of its acetic acid is driven off by the carbonic acid of the air, and the salt then yields with water a turbid solution, but which may be rendered transparent by adding to it a few drops of acetic acid.

Fig. 151.



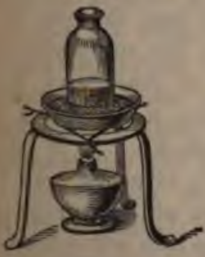
Basic Acetate of Oxide of Lead is prepared by digesting a solution of sugar of lead with oxide of lead, whereby part of the oxide of lead is dissolved.

This combination is kept in the apothecaries' shops in a liquid form, under the name of *solution of subacetate of lead*, or *Goulard's extract.* When mixed with spring-water it forms the so-called *lead-water*, which has a milky appearance, because some carbonate of lead is formed and separated by the carbonic acid of the water.

338. *Tartrate of Oxide of Lead.* — *Experiment.* — Mix a solution of two grains and a half of sugar of lead with a solution of one grain of tartaric acid; the white precipitate formed is collected on a filter, washed, and dried; it is insoluble *tartrate of lead.*

Experiment. — Fill a small phial one third full of dry tartrate of lead, and heat it in a sand-bath over a spirit-lamp, as long as fumes continue to escape. These have an empyreumatic odor, and burn with a blue flame, because they contain much carbonic oxide gas, which is generated by the carbonization of the tartaric acid. But the tartaric acid contains so much carbon, that a portion of it remains behind, intimately mixed with the metallic lead. The black substance obtained is a *pyrophorus*, which inflames spontaneously when poured out upon a stone, because, on account of its great porosity, it imbibes oxygen eagerly from the air. The yellow powder produced by the ignition is oxide of lead. If the phial is closed while it is yet hot, this pyrophorus will retain its inflammability for several days.

Fig. 152.



Hydrate of Oxide of Lead. — *Experiment.* — By adding ammonia to a solution of sugar of lead as long as a precipitate forms, hydrate of oxide of lead is obtained as a white powder. It is converted by heating into yellow anhydrous oxide of lead.

339. *Carbonate of the Oxide of Lead* (PbO, CO_2).

Add to a solution of sugar of lead a solution of carbonate of soda, as long as a precipitate is formed; the precipitate is carbonate of oxide of lead. The pigment known under the name of *white lead* is likewise carbonate of lead, but mixed with variable quantities of hydrated oxide of lead (basic carbonate of lead). This is prepared on a large scale in different ways.

a. According to the *English method*, litharge is mixed with vinegar to form a paste; this is then spread upon a stone slab, and exposed to the fumes of burning coke, the carbonic acid of which combines with the oxide of lead. The acetic acid acts in this case the part of a mediator. Like the nitric oxide in the sulphuric-acid chambers, it dissolves the oxide of lead, and then tenders it to the carbonic acid; when it has given up the first portion, it dissolves a second, &c. It is obvious that in this way a small quantity of acetic acid (or else of sugar of lead) is sufficient to aid in converting gradually a large quantity of litharge into white lead.

b. By the oldest, the *Dutch method*, a large number of jars, in which some vinegar has been poured, are arranged in a building upon a layer of stable-manure or tan, and rolls of sheet-lead are then suspended in the jars above the vinegar, and the whole covered with another layer of stable-manure. After the lapse of several months, the rolls of lead are found to be mostly, if not entirely, converted into white lead. The manure is decaying straw, the spent tan is decaying wood; decay is a slow combustion, or, what is the same thing, a slow conversion of organic substances into carbonic acid and water. In every combustion or decay, heat is liberated; this in the present case is sufficient to evaporate gradually the vinegar. Accordingly, oxygen, aqueous vapor, fumes of vinegar, and carbonic acid, are present in the air of the white-lead chambers. If you suppose that these substances combine with the lead in the succession just mentioned, the following order of changes will take place: — 1. oxide of lead; 2. hydrated oxide of lead; 3. acetate of oxide of lead; 4. basic carbonate of oxide of lead. Thus there is formed first oxide of lead, which, just as in the former process, is converted into carbonate of oxide of lead, through the mediation of acetic acid. The finest kind of white lead is that of Krems, called on the continent of Europe *white of Kremnitz.*

c. By the *French method*, the white lead is prepared in the moist way by conducting carbonic acid into a solution of basic acetate of lead (Goulard's extract). As was seen above (§ 337), a solution of sugar of lead can dissolve still another atom of oxide of lead; this is precipitated by the carbonic acid as white lead, whereby neutral acetate of lead is once more formed in the liquid, which is again digested with litharge, and afterwards treated with carbonic acid. In this way one pound of sugar of lead may be made gradually to dissolve, and again precipitate as white lead many pounds of litharge. The white lead obtained by this method has indeed a dazzling white color, but it does not possess so much body as that prepared in the English or Dutch manner. The cheaper sorts are obtained by mixing white lead with powdered sulphate of baryta; the latter remains behind when white lead is dissolved in diluted nitric acid. On heating white lead, the carbonic acid and water are expelled, and the yelow *residue is oxide of lead.*

it to the cork; the
with a gray coating,
metallic spangles will
finally filling up the
They consist of pure
After twenty-four hours, no trace
in the solution; it has been repla
zinc; the stronger zinc has abstrac
lead all its oxygen and acetic a
ment, not only the difference in th
of these two metals is clearly show
illustrates also the stochiometric
combination and decomposition;
sary to weigh the lead formed, an
before and after the experiment, t
weight of the precipitated lead is t
1294 to 407. An atom of lead ha
by an atom of zinc.

Lead and Sulph

metallic lead is obtained on a large scale. This ore is called *galena*, and is easily recognized by its grayish-black color, its shining metallic lustre, its cubic form, and its great specific gravity.

342. *Preparation of Lead.* — Sulphur is so firmly combined with the metals in the sulphurets, that it is impossible to expel it as easily as oxygen, for instance, by heating it with coal. Therefore a circuitous method must be adopted; namely, first to convert the metallic sulphuret into an oxide (*roasting*), and then to expel the oxygen (*reduction*). To effect this, the galena is heated continuously with access of air, whereby both the lead and the sulphur are combined with oxygen. The lead is converted into oxide of lead, which remains behind, and the sulphur into sulphurous acid, which escapes; some sulphate of lead is also formed at the same time. The roasted galena consists, therefore, essentially of oxide of lead (together with some sulphate of lead); this has now only to be heated with coal in a flame or blast-furnace, in order to separate the metallic lead (*lead-works*).

A second mode of freeing the lead from sulphur consists in heating the galena with a metal which has a greater affinity for sulphur, and replaces the lead. Such a metal is iron. Iron and sulphuret of lead are mutually converted into lead and sulphuret of iron. The iron acts here just in the same way that the zinc did in the formation of the lead-tree; one atom of iron replaces one atom of lead, therefore 350 pounds of iron can separate or throw down 1294 pounds of metallic lead.

343. *Lead Shot.* — Lead may be granulated by pouring it through a broom into water, as described under zinc. The same principle is applied in the manufac-

globular. As lead and arsenic a
health, shot should never be use
bottles.

BISMUTH, BISMUTHU

At. Wt. = 1330.—Sp. Gr.

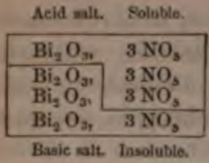
344. *Bismuth* is a metal chiefly
it frequently accompanies the coba
ready mentioned, in the smelting of
it separates as cobalt-speiss, nickel s
present. The metal is procured fr
from the native ore, by a very simp
curs both in the ores and in the spe
when it melts at a temperature whic
and a half times higher than that
consequently, it is only necessary to
erately upon an inclined plate, when
and flows off below, while the othe
gether with the gangue, remain

with brisk ebullition. A portion of the fumes condense on the charcoal, coating it with a yellow powder; this is oxide of bismuth ($Bi_2 O_3$). If you throw the glowing metallic bead into a small paper box, it divides into small globules, which, while still glowing, will skip about for some moments. An odor like that of garlic, which is frequently emitted during the ignition, proceeds from arsenic, small quantities of which occur in almost all commercial bismuth.

346. *Experiment.*—Melt together in a ladle two drams of bismuth, one dram of lead, and one dram of tin; the alloy formed has the very remarkable property of becoming completely liquid when thrown into boiling water. Bismuth melts at 250° C., lead at 320° C., tin at 230° C., and yet the mixture of these three metals melts below 100° C. By increasing the quantity of lead, alloys may be prepared *which readily become liquid* at any temperature desired above 100° C. They are sometimes employed as safety-plates in steam-boilers. The heat of the steam increases with the tension of the steam in the boiler; therefore the alloy, to be used, has only to be so selected that, in case of a too great increase of steam, the plate may be melted by the heat of the steam before an explosion of the boiler itself can take place. As these alloys, in their melted state, do not burn the wood, they are also very well adapted for making metallic copies of engraved wooden moulds, for calico-printing, and block-impressions. This alloy is called *Rose's metal*, after the inventor.

347. *Experiment.* — Bismuth is most easily dissolved by *nitric acid.* Dissolve some bismuth at a moderate heat in this acid, and pour the solution into a large quantity of water; it becomes very turbid, and after standing quietly, a white precipitate subsides, which contains

only one fourth as much nitric acid as the salt which crystallizes out from the bismuth solution when you let it cool. This powder is *subnitrate of oxide of bismuth*, and is used as a medicine. A small proportion of oxide of bismuth, with a large proportion of nitric acid, remains dissolved in the liquid. The annexed diagram denotes the decomposition hereby taking place, which is of more general interest, as showing that the affinities of bodies for each other may be changed by greater or less dilution with water.



The salts of bismuth may be recognized by this behaviour with water. By adding sulphuretted hydrogen to the solution remaining from the former experiment, you obtain a brownish-black precipitate of *sulphuret of bismuth.*

COPPER, CUPRUM (Cu).

At. Wt.=396.—Sp. Gr.=8.8.

348. In ancient times copper was chiefly obtained from the island of Cyprus, where its ores were found in great abundance; this explains the name, *cuprum.* It being afterwards deemed expedient to give mythological names to the metals, copper received the name of *Venus*, the protecting goddess of Cyprus, and the sign ♀. Copper possesses several excellent properties, which have rendered it an exceedingly useful metal.

a.) It is *ductile* and at the same time very *strong* and *tenacious*, so that it may be hammered out into plates, which, even when very thin, still hold firmly together.

b.) It *fuses with difficulty* (its point of fusion being

1200° C.); therefore it is excellently adapted for such articles as are to be exposed to a great heat, for instance, kettles, pans, boilers, moulds for casting, &c.

c.) When exposed to the air, it *suffers from rust much less* than iron; for this reason, copper utensils are much more durable than iron ones. Sheet-copper is employed for sheathing ships, and for roofing towers and other buildings.

d.) It is quite hard, and therefore wears out but slowly on use, as in copper plates for engravings, and rollers of print-works.

e.) With zinc, tin, and nickel, it forms very useful *alloys*, such as brass, tombec, bronze, bell-metal, cannon-metal, German silver, &c.

f.) It is precipitated from its solutions by the galvanic current as a firm coherent mass; on this principle, impressions of other bodies are produced by the modern process of *electro-metallurgy.*

g.) It yields with oxygen and several acids insoluble combinations of a beautiful green and blue color, of various application in painting.

Although copper possesses no smell, yet it imparts to moist hands and to the water which has long been standing in vessels made of it (as boilers or kettles), a peculiarly disagreeable odor.

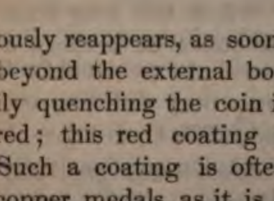
Experiments with Copper.

349. In the moist air, copper slowly turns gray and afterwards green (native mineral-green). Copper, like zinc, attracts, not merely oxygen and water, but also carbonic acid from the air; the green coating is the *hydrated basic carbonate of copper.* In Siberia this combination occurs in large beds in the earth, and is then called *malachite.* The celebrated Russian copper is prin-

cipally obtained from it; and its beautifully mottled varieties are, like marble, formed into works of art, and are used for ornamenting palaces, &c. This green body, on receiving yet more carbonic acid, acquires a beautiful blue color, and is converted into *sesquibasic carbonate of copper*, which likewise occurs native as a copper ore, under the name of *blue carbonate of copper*. The artificially prepared is called *mountain blue*, and is employed as a pigment, particularly for painting walls, its color not being changed, like Prussian blue, by the lime of the walls.

350. *Experiment.* — Hold a brightly polished copper coin over the flame of a spirit-lamp; the color changes from yellow to crimson, violet, and blue, and finally passes over to a dark gray. These iridescent hues present a particularly beautiful appearance by holding the coin obliquely in the middle of the flame, and moving it to and fro; in the centre of the flame the coating vanishes, but it instantaneously reappears, as soon as the coin reaches or extends beyond the external border of the flame. On speedily quenching the coin in water, it becomes brownish-red; this red coating is *suboxide of copper* (Cu_2O). Such a coating is often intentionally produced upon copper medals, as it is less liable to change in the air than the brilliant metallic copper (*bronzing of copper, bronze medals*). Suboxide of copper, when thrown into melting glass, colors it *blood-red;* in this manner a beautiful red color is flashed on glass in the glass factories. This accounts, also, for the red color of the slag

Fig. 154.



which forms during the calcination and fusion of copper.

351. *Protoxide of Copper* (Cu O). — If the copper coin is left for some time in the point of the flame, it acquires a black appearance; *protoxide of copper* is formed, which has a black color, and contains as much again oxygen as the red suboxide. If suddenly quenched, the oxide flies off, and the red appearance of the coin shows that the suboxide is also present beneath the film of the protoxide. By long-continued ignition the whole mass of the coin may be converted into suboxide, and by still longer heating, completely, at last, into protoxide. The glowing cinders, which fall off in the workshops of the coppersmith (copper scales), consist of a mixture of the suboxide with the protoxide.

Experiment. — Triturate a small quantity of borax with a scale of the black oxide of copper, and melt it into a bead on a platinum wire before the blow-pipe; the oxide of copper will dissolve in the borax, and form a *green* glass. Oxide of copper is made use of in glass and porcelain painting. If introduced into the interior flame, the green color passes over to red, because the oxide is there reduced to suboxide of copper.

Oxides of copper may also easily be prepared in the humid way, but they have then a very different color.

352. *Hydrated Oxide of Copper* (Cu O, H O). — *Experiment.* — Add to a solution of the previously mentioned *blue vitriol*, or sulphate of copper, a solution of caustic potassa; a greenish-blue powder is precipitated; it is *hydrated oxide of copper*. The black oxide yields, also, chemically combined with water, a blue body. Mixed with gypsum this forms a light powder, the well-known *Bremen blue*. Boil a portion of the

liquid; the precipitate will become black, because at the boiling point the combination between the oxide of copper and the water is destroyed; — another example of chemical decomposition occasioned by mere elevation of temperature.

353. *Ammoniated Oxide of Copper.* — *Experiment.* — Repeat the former experiment, but instead of potassa take ammonia; here also the hydrated oxide of copper is first precipitated, but this is redissolved by adding more ammonia, forming a *superb blue liquid.* Ammonia is therefore a test for salts of copper. Pour upon the blue liquid an equal quantity of strong alcohol, and direct the stream against the side of the glass, so that the alcohol may float on the surface; after the lapse of twenty-four hours, a mass of dark-blue acicular crystals is perceptible, which consist of a combination of sulphate of copper with ammonia, and are called *ammonio-sulphate of copper.* By dissolving them in water, the *blue liquid* of the apothecaries' show-bottles is prepared. The alcohol effects that which is otherwise attained by boiling, namely, a removal of the water; it withdraws from the blue liquid a portion of its water, and the double salt, which is insoluble in alcohol, is separated. The water may be abstracted, also, in this way from other solutions of salts, which would undergo a decomposition on the evaporation of the water by heat.

354. *Experiment.* — Add to a diluted solution of blue vitriol a small quantity of pulverized sugar of milk, and then rather more liquid potassa than is necessary to precipitate the hydrated oxide of copper, and heat the mixture; the blue color will soon pass into a yellowish-red. The yellowish-red precipitate is *suboxide of copper*, which is formed from the protoxide of copper,

because the sugar is able to abstract from the latter half its oxygen. The same compound, but of a more beautiful red color, is obtained by boiling verdigris with vinegar, and then adding some honey to the solution obtained, and again boiling. Thus is easily explained why a red deposit always subsides from the oxymel of subacetate of copper in the apothecaries' shops; in the slow separation which occurs in the latter case, small distinct crystals are frequently formed.

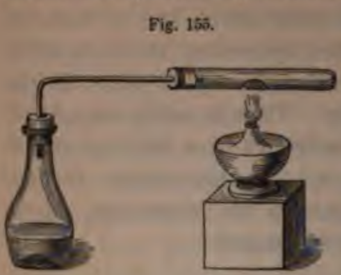
Reduction of the Copper Compounds to Metals.

355. *Experiment.* — Rub together some grains of blue vitriol, carbonate of soda, and *charcoal;* ignite the mixture strongly for some minutes before the blowpipe, and then elutriate the black mass with water; numberless small spangles of metallic copper will remain behind on the bottom of the vessel. The carbonate of soda takes the sulphuric acid from the blue vitriol, and the charcoal the oxygen from the oxide of copper.

356. *Experiment.* — If half an ounce of blue vitriol is heated to boiling with an ounce and a half of water in a porcelain bowl, and then boiled a few minutes with some granulated *zinc*, the metallic copper separates as a powder, since the zinc has a greater affinity than copper for oxygen and for sulphuric acid. The powder obtained is washed, and then boiled with water and a few drops of sulphuric acid, in order to remove all the zinc. It must be dried quickly, but not at a high heat, for copper in this state of minute subdivision attracts oxygen with more avidity than when it is in a compact mass.

357. *Experiment.* — Introduce some hydrated oxide of copper into a test-tube, the bottom of which is

Fig. 155.



broken out, heat it, and then pass over it a stream of *hydrogen*, which is evolved by zinc and diluted sulphuric acid; in the heat, the hydrogen abstracts from the oxide of copper its oxygen, and forms with it water, which escapes in company with the hydrated water. This method is frequently employed for the reduction of ores on a small scale.

Fig. 156.

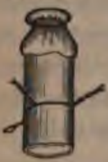
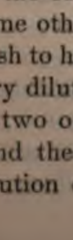


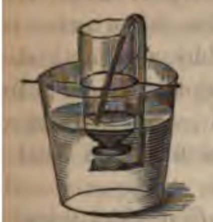
Fig. 157.



358. *Experiment.* — Push an iron rod into a good-sized, large-mouthed phial, forcibly enough to break out the bottom, file off the sharp edges of the fractured part, and bind a moistened bladder over the mouth of the phial. Then twist a wire firmly round the phial, in such a manner as to form two or three supports, by means of which it may be suspended in a tumbler.

Let a strip of strong sheet-zinc, of the width of the finger, and five inches long, be soldered to a strip of thin copper plate, ten inches long, and bend the strip of copper as represented in the annexed figure. Put a coin upon the lower horizontal part of the copper strip, — for instance, a bright dollar, — or some other metallic object, the impression of which you wish to have. Now fill the phial three quarters full with very diluted sulphuric acid (one dram of sulphuric acid to two ounces of water), introduce the zinc, and suspend the apparatus in a tumbler, in which a saturated solution of blue vitriol, and also a few whole crystals

Fig. 158.



of blue vitriol, have been put. In the course of a few minutes the coin will be covered with a thin film of metallic copper, and after several days with a layer several lines in thickness, which may be removed as a coherent mass. Tallow and wax must be smeared over those parts of the coin and plate on which the copper is not to be deposited. The sunk impression thus obtained may be used in the same way again, instead of the coin, as a mould for obtaining a raised impression. When the evolution of the gas in the phial has ceased, a few drops of strong sulphuric acid may be stirred in, or the liquid, which contains sulphate of zinc in solution, may be replaced by a fresh supply of diluted sulphuric acid. Salt water may also be used instead of sulphuric acid, but then the separation of the copper takes place more slowly.

The decomposition of the blue vitriol has, in this case, been effected by the *galvanic current*, which is always generated when different kinds of metals come in contact, or are introduced into different liquids. The bladder is a porous substance, through which the galvanic current may pass. Galvanism here takes the place of the plastic artist, and hence the term *galvanoplastic*, applied in Germany to electro-metallurgy. A solution of gold or silver may be decomposed in the same manner (galvanic gilding and silvering).

Copper and Acids.

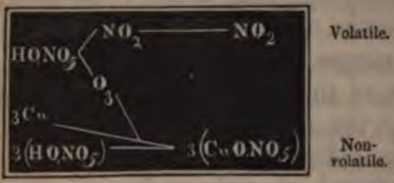
359. *Chloride of Copper* (Cu Cl). — *Experiment.* — If muriatic acid is added to oxide of copper, a green solution is obtained, and from it, by evaporation, a green salt, *chloride of copper*, or muriate of oxide of copper.

Introduce some of it into the wick of a spirit-lamp; it dissolves in the alcohol, and colors the flame green. Write on paper with a very diluted solution of it; the color of the writing changes on heating, and again on cooling, as in the case of chloride of cobalt (§ 308). Metallic copper is dissolved, but very slowly, and with access of oxygen.

For *Sulphate of Oxide of Copper, or Blue Vitriol*, see § 175.

360. *Nitrate of Oxide of Copper* ($Cu\,O, N\,O_5 + 5\,HO$).

Copper dissolves very readily in nitric acid, forming a blue liquid (§ 162); if the solution is set aside in a warm place, blue crystals of *nitrate of copper* are deposited, which deliquesce in the air. The accompanying diagram serves to illustrate the process attending the solution of copper, as well as of most other metals, in nitric acid. It is already known that the nitric oxide gas which escapes becomes nitrous acid on coming into contact with the air.



Experiment. — Envelop quickly in *tinfoil* some crystals of nitrate of copper, moistened with a drop of water, and press the parcel compactly together, and put it upon a stone; flames and smoke will soon break forth from the bubbling mass, because the tin overpowers the nitric acid, and by means of its oxygen becomes oxidized into oxide of tin.

Oxide of copper forms, with phosphoric, arsenic, oxalic, and silicic acids, insoluble blue or green *compounds*, in the same way as with carbonic acid.

361. *Verdigris.* — *Experiment.* — By sprinkling a copper coin from time to time with vinegar, it becomes gradually covered with a green coating. When copper is rusted merely by exposure to the moisture of the atmosphere, or of the earth, *basic carbonate of copper* is formed; but when the rusting is effected by vinegar, *basic acetate of copper* is formed. The latter is the verdigris of commerce. It is prepared on a large scale, either directly from copper and vinegar (green or German verdigris), or indirectly by packing sheets of copper with the refuse of pressed grapes, since the juice yet adhering to the mash gradually passes over into vinegar (blue or French verdigris). Verdigris boiled with vinegar gives a blue solution, from which, on cooling, dark green crystals of neutral acetate of oxide of copper ($Cu\,O\,\bar{A} + H\,O$) are deposited (crystallized or distilled verdigris).

Verdigris, like all the salts of copper, is *very poisonous;* the white of eggs and milk are efficacious antidotes. Polished iron, ammonia, sulphuretted hydrogen, and especially ferrocyanide of potassium (§ 292), serve for the detection of salts of copper.

Copper and Sulphur.

362. *Experiment.* — If some sulphuretted hydrogen water is added to a solution of any of the copper salts, a black precipitate of *sulphuret of copper* is produced (§ 131). Heat this, after it has settled and the liquid has been decanted, with some drops of nitric or muriatic acid; the sulphuret of copper is decomposed and dissolved, while nitrate or muriate of copper is formed. This mode is universally employed on a small scale, especially in analysis, in order to convert metallic sulphurets into soluble salts.

363. *Preparation of Copper.* — The *sulphuret of copper* is the most common ore from which copper is extracted. It is seldom found pure, but mostly combined with sulphuret of iron, as in *copper pyrites.* The process of the reduction and smelting of copper is, accordingly, very tedious, as not only the sulphur, but also the iron, must be got rid of. This is effected, — 1st, by roasting in the air, whereby the copper is converted into oxide of copper, the iron into black oxide of iron, and the sulphur into sulphurous acid; 2d, by melting the roasted ore with charcoal and some silicious substance, by which means metallic copper and carbonic oxide are formed from the oxide of copper and the charcoal, and silicate of protoxide of iron (iron slag) from the protoxide of iron and quartz. What appears thus simple is, in reality, so difficult an operation, that the roasting and melting must often be alternately repeated ten or twenty times in order to remove all the iron and sulphur. The melted mass, which is obtained when about half the iron and sulphur is abstracted, is called *matte* (crude copper); and *black copper*, when it contains only about five per cent. of these two substances. The complete refining of black copper is effected by melting the metal again, exposing it at the same time to the action of the air, whereby the iron, sulphur, and other foreign metals which may be present, as lead and antimony, are oxidized before the copper. When the black copper contains silver, it is subjected to the process of liquation.

The operation of working the copper is much easier when the ores are combined with oxygen instead of sulphur, as they yield the metallic copper by merely heating with coal; but such ores are of too rare occurrence in nature to yield sufficient copper to meet the demand.

364. *Alloys of Copper.* — Copper forms very important alloys with several other metals.

Gold and *copper* form the common gold, *silver* and *copper* the common silver, from which gold and silver articles and coins are made.

The well-known *brass*, and other metallic compounds having the appearance of gold, such as tombac, similor, prince's metal, red brass, &c., are composed of zinc and copper. Spurious *gold-leaf* is made by hammering out tombac into exceedingly thin leaves, which, when finely pulverized, constitutes the so-called *gold bronze*. *Purple* or *copper bronze* is prepared by gently heating the gold-colored bronze till it turns to a purple-red color.

Zinc, *nickel*, and *copper* constitute the ingredients of German silver (*packfong*, *white copper*).

Tin and *copper* form a very hard gray alloy, from which statues, cannons, bells, mirrors, &c., are cast (*bronze*, *gun-metal*, *bell-metal*, *speculum metal*).

MERCURY, HYDRARGYRUM (Hg).

At. Wt. = 1250. — Sp. Gr. = 13.5.

365. We have in *mercury* the only metal which is *fluid* at ordinary temperatures; for this reason, and also on account of its silver-white brilliancy, it has been called *hydrargyrum* (water-silver or liquid silver). But subsequently, from its mobility, it was dedicated to *Mercury*, the most active of the ancient gods, and received his name, the symbol ☿ being at the same time assigned to it. Even now, quicksilver and its various medicinal preparations, such as calomel and corrosive sublimate, are called mercurial remedies. In the northern parts of Siberia mercury becomes solid every winter,

only three and a half times
water), and it is therefore easil
tilled.

Experiment. — Fasten to the co
ing mercury a piece of wood, affi
the latter some genuine gold-leaf;
days, will have assumed a white co
into an alloy of gold and mercury.
this, that fumes of mercury must
air of the phial, and that mercury, li
slowly even at ordinary temperatur
mercury, and the preparations of m
jurious; they first produce involunt
afterwards lingering, dangerous n
in experimenting with mercury, not
of the fumes should be avoided, but
and decanted over a bowl, so that, i
should happen to be spilt, it may no
Spirit-thermometers only should be
ing-apartments and sitting-rooms, s
dental breaking of the mercurial th
mosphere would be vitiated by th
into the chinks

&c. (§§ 16, 24, 93). Its chief use in areometers is to lower the centre of gravity, thereby forcing the instrument to float in an upright position. In the less accurate areometers, lead shot are frequently substituted for mercury.

Mercury and Acids.

366. Mercury, if quite pure, retains its metallic lustre in the air and water, and it is therefore ranked among the *noble* metals; but if it is mixed or adulterated with other metals, as lead, tin, or bismuth, a gray film will gradually form upon its surface. On account of the slight affinity of the noble metals for oxygen, their oxides cannot be prepared directly by exposing them to the air, or by heating them to redness, but only indirectly, the best way being to treat the metals with acids. The most powerful solvent for mercury is *nitric acid;* the cheapest is sulphuric acid.

367. *Nitrate of Suboxide of Mercury* ($Hg_2\,O, N\,O_5$). — *Experiment.* — Pour into a porcelain dish one ounce of mercury, one dram of water, and half an ounce of nitric acid; cover the vessel and place it aside for several days; you will then find the mercury covered with white crystals; they are the nitrate of the *suboxide of mercury.* In the *cold*, two atoms of mercury take up only one atom of oxygen from the nitric acid. Put a part of the crystals into a phial, and pour over them some water; a milky turbidness is produced, as in the solution of bismuth (§ 347), but it disappears again on the addition of a few drops of nitric acid.

This solution of suboxide of mercury serves for the following experiments: —

368. *Suboxide of Mercury* ($Hg_2\,O$). — *Experiment.* — To a part of the solution of suboxide of mercury is

added a solution of potassa; a *black* precipitate of *suboxide of mercury* is formed. This preparation must be kept in an opaque phial, because it is resolved by the light into oxide of mercury and metallic mercury. If ammonia is used instead of the potassa, a triple combination is obtained of suboxide of mercury, ammonia, and nitric acid,—black or Hahnemann's suboxide of mercury, used in Germany as a medicine.

369. *Experiment.*—If a drop of the solution of mercury is rubbed upon a copper coin, the mercury separates as a metal, and effects a *false silvering* of the copper.

Experiment.—Make a stroke across a brass plate with a wooden stick that has been dipped in the solution of mercury; if the plate is afterwards bent at this place it will break, as though it had been cut; because the reduced mercury penetrates the brass with great quickness, and renders it brittle. Thus the brazier can make use of this solution instead of shears.

370. *Subchloride of Mercury* ($Hg_2 Cl$).—*Experiment.*—Add some muriatic acid, or a solution of common salt, to a part of the diluted solution of the suboxide of mercury; a heavy white precipitate of *muriate of suboxide of mercury*, or *subchloride of mercury*, is produced, which is *insoluble* in water. When finely washed and dried, this salt of mercury forms the highly important medicine known as *calomel* (*precipitated*). If some of it is moistened with potassa or lime water, it becomes black, owing to the suboxide of mercury being set free; thus is explained the Greek name *calomel* (καλός, beautiful, μέλας, black). This combination is also slowly decomposed by light. Formerly, subchloride of mercury was universally prepared from chloride of mercury and metallic mercury, which were rubbed together and sublimed (*sublimed calomel*). By this process Hg Cl

d Hg are converted into $Hg_2\,Cl$, a heavy, crystalline, ite mass, which is pulverized and washed out many nes with boiling water. The powder thus obtained s a slight yellowish tinge.

371. *Nitrate of the Peroxide of Mercury* ($Hg\,O$, O_5). — *Experiment.* — Dissolve in a flask, at a moder-e heat, some mercury in nitric acid, and when com-etely dissolved, boil the liquid briskly for some min-es. While boiling, the mercury combines with as uch again oxygen as in the cold, and accordingly *ni-ute of peroxide of mercury* is produced, which crystal-es from the liquid on cooling. A solution of this salt ves, with potassa or lime-water, a *yellowish-red* pre-pitate of peroxide of mercury, but it is *not* rendered rbid by muriatic acid or common salt.

372. *Peroxide of Mercury* ($Hg\,O$). — *Experiment.* — eat gradually in a test-tube some of the crystals of e nitrate of peroxide of mercury, till they cease to ve off fumes; the nitric acid escapes, partly decom-sed into nitrous acid, the oxide of mercury remains hind. Its red color, however, appears first on cool-g; as long as it is hot, it looks black. It is resolved too strong a heat into oxygen and metallic mercury 56).

373. *Perchloride of Mercury* ($Hg\,Cl$). — *Experiment.* — eat some peroxide of mercury with muriatic acid, and ntinue adding the latter till a complete solution is tained; the white prismatic crystals which separate cooling are muriate of peroxide of mercury, or *per-loride of mercury*, — one of the *most violent poisons.* ne same compound is obtained on a large scale, in ite, transparent, heavy masses, by the sublimation of e sulphate of oxide of mercury with common salt; nce its common name, *corrosive sublimate* (mercurius

sublimatus corrosivus). Potassa turns calomel black, but corrosive sublimate yellowish-red. Poisonous substances commonly have the property of protecting vegetable and animal substances from decay, and perchloride of mercury possesses this power in a high degree. For this reason, wood for ship-building, and sleepers for railroads, are saturated with a solution of it in water (*Kyanizing*); the plants of herbariums are passed through a solution of it in alcohol, &c. It must not be forgotten, that these things themselves are thereby rendered poisonous. In cases of poisoning, large quantities of whites of eggs must immediately be administered, as the albumen forms with the chloride of quicksilver an insoluble compound.

374. If ammonia is added to a solution of perchloride of mercury, then red oxide is not precipitated, but a white body, which is likewise (as in § 368) a triple compound, consisting of mercury, chlorine, and ammonia. It is kept in the apothecaries' shops as an external remedial application, under the name of *white precipitate.*

375. *Experiment.*— Add some salt of tin (protochloride of tin) to another portion of the solution, and heat the liquid; a gray powder will separate; this is *mercury in a state of extreme comminution.* If you boil it with muriatic acid, after having decanted the liquid, the powder finally forms into globules. The protochloride of tin has so strong a tendency to pass over into perchloride, that it abstracts the chlorine from the chloride of mercury. This action is made available in analysis for detecting the salts of mercury.

Mercury may be minutely divided also by long trituration with viscous substances, as fat, tallow, wax, &c., so that no particles of it can be discerned by the naked ye. In this [illegible] la ters are prepared by the [illegible]

Mercury and Sulphur

376. *Sulphuret of Mercury* [illegible] — [illegible] — If a solution of [illegible] little sulph[illegible] monium a [illegible] ing more of the precipitating [illegible] brown and [illegible] *phuret of mercury.* [illegible] mixing [illegible] bing it for a [illegible] *eral).* [illegible] in a g[illegible] obtained [illegible] into the [illegible] of quic[illegible] bar. [illegible] precisely [illegible] great [illegible] finest exa[illegible] red and [illegible] phur is [illegible] one ounce [illegible] milion is [illegible] moist way [illegible] sulphur. [illegible] pure. [illegible] ting, at the same [illegible] adulterated [illegible] behind. [illegible] prejudicial [illegible] mercury.

Cinnabar also occurs in nature, and we have in it the most important ore, from which we obtain mercury on a large scale. Small globules of pure mercury are also found in many porous stones.

377. *Preparation on a Large Scale.* — *Experiment.* — Mix a little vermilion with half its quantity of iron filings, and heat the mixture in a dry test-tube; small globules of mercury will soon deposit themselves on the upper cooler portions of the glass, while the sulphur remains combined with the iron. Mercury is obtained in a similar manner from native cinnabar, by distilling it with iron or lime in large iron retorts; the foreign earths remain behind in the latter. This heavy liquid is imported either in leather bags, iron flasks, or hollowed out bamboo-canes.

378. *Amalgams.* — *Experiment.* — Introduce a globule of mercury into a porcelain dish, put upon it a piece of lead, and let them remain for some time in contact; both metals will intimately combine together. If the proportion of mercury is small, a friable mass is produced, but by increasing the quantity, a paste, and, if still more is added, a liquid solution, is obtained. Mercury will combine in a similar manner with most of the metals, forming what are called *amalgams*. The *amalgam of tin* is especially important for silvering glass, so that the rays of light falling upon the surface of the glass may be reflected by the bright coating of the amalgam. Such glasses are called *mirrors.*

SILVER, ARGENTUM (Ag).

At. Wt. = 1350. — Sp. Gr. = 10.5.

379. *Silver* conveys to us a distinct conception of what is understood by a *noble* metal. We can let a

dollar of pure silver remain exposed to the air, we can throw it into the water, or bury it in the earth; it does not rust. We can subject it to the greatest heat; it may perhaps change its form, and melt (at about 1000° C.), but it does not oxidize nor volatilize. Silver has also a *higher value* than most other metals, not only on account of its *unchangeableness*, but because its ores are of comparatively rare occurrence in nature, and the process of obtaining them is more costly than that of other ores. A pound of silver is worth about fifteen dollars. It is principally on account of these two circumstances that silver and gold have been made to serve as the medium of exchange in the sale and purchase of commodities,—that they are used as *money*. The beautiful lustre of silver, and its extraordinary ductility, have moreover rendered it a favorite and appropriate metal for various articles of luxury, and for plating other metals. The old name for silver is *Luna* (☽).

Alloys of Silver.—As pure silver is very soft, and would quickly wear out in using, it is generally alloyed with copper, whereby it is rendered harder, without losing its ductility. If the proportion of copper is only one fourth, the silver still retains its beautiful white color; but if more copper is added, the alloy becomes yellow, and finally red, by use. It has been agreed to call a quantity of pure silver, weighing 8 ounces, a *fine mark*. If the sample is an alloy of silver and copper, the question is always asked, What is the proportion of pure silver in 8 ounces?. If it amounts to 7½ ounces, the silver is said to be 7½ ounces fine; if 6, or 4, or 2 ounces of silver are contained in it, it is understood to be 6, or 4, or 2 ounces fine. Accordingly silver 6 ounces fine contains three fourths of silver and one fourth of copper, from which plate and the larger coins, for instance, dollars, are made.* In the two-ounce silver, on the contrary, the proportions are one fourth of silver and three fourths of copper; this is used for some of the smaller modern German coins, for instance, grosch and half-grosch pieces, &c. When recently stamped, they are yellow, but the surface of them is rendered white by boiling them with cream of tartar and water, because some of the copper is thereby dissolved, and consequently a thin coating of pure silver is produced. By *due weight* is understood the weight of a coin; by *value*, the fineness of the silver employed.

Experiments with Silver.

380. In order to oxidize silver, it must be treated with acids; it dissolves most readily in *nitric acid.* In the following experiments, care must be taken not to touch the solution of silver with the finger, as the skin is stained *black* by it.

Nitrate of Oxide of Silver.—*Experiment.*—Add some nitric acid to a silver coin placed in a beaker-glass, which must be put in a warm place; if after a few days the coin is not entirely dissolved, add more nitric acid, and wait till the solution is completed. The blue solution consists of oxide of silver and of oxide of copper, both combined with nitric acid.

To separate these two metals from each other, put some bright copper coins into the solution, and set it aside in a warm place for a few days, occasionally giving it a circular motion. The separated laminæ are pure silver, which are to be digested with ammonia, until this ceases to be colored blue. The silver, after being washed and dried, is dissolved for the second time in nitric acid, and the liquid, diluted with water, is kept as *solution of silver*.

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* "The gold and silver coins [Federal Money] contain nine tenths pure metal, and one tenth alloy."

Lunar Caustic. — By evaporating this solution, *nitrate of oxide of silver* ($Ag\,O,\,N\,O_5$) is obtained, in white tabular crystals. When these are fused and formed into slender sticks by casting in brass moulds, they constitute *lunar caustic*, known as a corrosive agent, employed for removing proud-flesh, warts, &c. (fused nitrate of silver). It not only attacks the texture of the skin and dyes it black, but also other organic substances; on account of this property, it is often employed for dyeing black the hair, and also bones and ivory, as in chess-men, &c. The black color proceeds from the separation of the oxide of silver. Nitrate of silver forms also the indelible ink used for writing on linen.

381. *Experiments with Nitrate of Silver.*

Experiment a. — Place a small piece of lunar caustic upon charcoal, and heat it before the blow-pipe; it deflagrates and yields *metallic* silver, which may be easily fused at a stronger heat.

Experiment b. — Add some ammonia to a solution of lunar caustic; the dark-gray precipitate is *oxide of silver* ($Ag\,O$). If more ammonia is added, it is redissolved. It would be dangerous to continue this experiment any further, as the oxide of silver combines with ammonia and forms *fulminating silver*, which explodes violently on percussion or friction. Another explosive compound may be prepared by uniting the oxide of silver with fulminic acid.

Experiment c. — *Chloride of Silver.* — Dilute with water part of the solution of silver obtained in § 380, and add to it muriatic acid, or a solution of common salt;

you obtain a white curdy precipitate of *chloride of silver* ($Ag\,Cl$). This precipitate is so insoluble in water, that it will impart a cloudiness to a solution of silver diluted a millionfold (§ 187); it is, however, easily dissolved by ammonia (test of salts of silver). This relation of the solution of silver to common salt is made use of by silversmiths for testing silver alloyed with copper, as the quantity of pure silver in the alloy may be estimated from the amount of the solution of salt required for its complete precipitation (humid assay of silver). Chloride of silver is also called *horn-silver*, having formerly received this name from the horn-like appearance it assumes on melting.

Experiment d. — After having decanted the supernatant liquid, rub the *chloride of silver* with a cork upon a sheet of paper, and let it dry in a dark place, — in a drawer, for instance; it remains white. Now inclose the sheet in a book, so that one half may be exposed to the light; this part soon acquires a violet, and finally a black color, while that protected from the light remains white. Thus *light alone* is capable of destroying the affinity between silver and chlorine; the chlorine escapes, but the silver remains, and in this state of fine subdivision its color is *black.* On this action of the solar light on certain substances were founded the experiments made some years since by the natural philosopher Daguerre, who at length succeeded in making use of the sun as delineator, and of the salts of silver (especially the compounds of silver with chlorine, bromine, and iodine) as crayons or India ink, in producing the so-called *Daguerreotype* or *photographic* impressions.

Experiment e. — *Sulphuret of silver.* — If you add sulphuretted hydrogen to a solution of silver you obtain a black precipitate of *sulphuret of silver* ($Ag\,S$). This compound occurs in nature as the most important silver ore; it is called *silver-glance.* Silver is likewise found in a pure state, or in combination with arsenic and antimony, as *red silver ore.*

382. *Preparation of Silver on a Large Scale.* — The preparation of silver from its ores is adapted to the other ores with which the silver ores are commonly mixed. The three following methods are those most frequently resorted to.

a.) *Cupellation.* — Galena generally contains small quantities of silver. In order to extract this, the galena is first reduced, by roasting and smelting with charcoal, to metallic lead, in which the silver is also contained. This mass, containing silver, is then put into a kind of reverberatory furnace, called the *refining hearth*, and which is hollowed out like a kettle; it is there heated for a day, while a constant current of air is passed over the metal, until all the lead is at last converted into oxide. The oxide of lead melts in the heat, and flows off partly as litharge through a tube, and partly soaks into the porous mixture of clay and lime, which has been firmly beaten down on the hearth of the furnace; but the silver, which is not oxidized, remains behind in a metallic state (*refined silver*). This is rendered still purer by being again fused in clay-basins (smaller cupels), which absorb the remainder of the litharge (*fine silver*). If other less noble metals are present in the silver ore, they are likewise oxidized and carried down into the cupel by the litharge. These methods can also be employed on a small scale for estimating the alloys of silver (*assay by the cupel*).

b.) *Liquation Process.* — Many of the copper ores also contain silver, and yield, on reduction, a copper containing silver (§ 363). The silver is fused and extracted from this ore by means of *lead*, in the same way as potassa is dissolved and extracted from wood-ashes by water. The calcined ore is mixed with a large proportion of lead, and then fused and run into pigs, called *liquation-cakes*, which are placed, with layers of charcoal, upon an inclined hearth. When the coal is ignited, the heat is indeed sufficient to melt the lead, but not the copper; consequently the lead flows off, and carries with it the silver, whilst the copper remains behind. This mixture of lead and silver is finally, as described at *a*, converted into metallic silver and oxide of lead in the refining-hearth.

c.) *Process of Amalgamation.*— Silver is often extracted by means of *mercury* from the ores containing pure silver or sulphuret of silver, but no admixture of lead. But in the case of silver-glance the metallic silver must first be separated from the sulphur. This is done by two operations. In the first, the stamped ore is roasted with common salt, by which process chloride of silver and sulphate of soda are formed; in the second, the roasted ore is mixed with water, iron, and mercury, and kept in constant agitation for some time in closed casks. Chloride of iron and metallic silver are thereby formed, the latter of which is dissolved in the mercury. The excess of mercury is then filtered off, and a solid silver amalgam is obtained by subjecting it to pressure, and the mercury is at last completely removed from the amalgam by distillation.

GOLD, AURUM (Au).

At. Wt. = 2458.—Sp. Gr. = 19.2.

383. Though *gold* is found in most countries, yet it is disseminated so sparingly, and the separation of it

from the rocks or the river-sand in which traces of it occur is attended with so much labor, that it is rendered the most costly of our metals. The value of gold is about fifteen times greater than that of silver.[*] Its unchangeableness, its beautiful color, its high lustre, and great density, have stamped it as the noblest metal, — the king of metals. It was formerly regarded as the symbol for the king of the stars, and was called Sol, or Sun (☉). It surpasses even silver in ductility, may be beaten out into extremely thin leaves (gold-leaf), and a single grain of gold may be drawn out into a wire five hundred feet in length. As it always exists in a metallic state in nature, and has a very great specific weight, the most simple method of separating it from the sands, or from the stamped ores, is either by washing with water or by amalgamation with mercury.

Pure gold, like pure silver, is exceedingly soft, and quickly wears out in using; therefore, when it is to be manufactured into coins or articles of luxury, it is alloyed with other metals, usually *silver* and *copper*, to render it harder. The quantity of pure gold contained in a mass is expressed by the word *carat*, the standard number not being 8, as in silver, but 24. A mark of gold (8 ounces) is divided into 24 parts or carats. If gold is said to be 18 carats fine, it is understood that the mass consists of three fourths (18 parts) of gold, and one fourth (6 parts) of alloy; if 6 carats fine, of one fourth (6 parts) of gold, and three fourths (18 parts) of alloy, &c.

384. *Parting of Gold.* — In order to obtain fine gold from alloyed gold, or to separate it from silver con-

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[*] "Gold is regularly purchased by the Bank of England at the rate of £3 17*s.* 9*d*, and issued at the rate of £3 17*s.* 10½*d.* per ounce of 22 carats (eleven twelfths) fine." — Waterston's *Cyclopædia of Commerce.*

taining gold, it is boiled with concentrated *sulphuric acid*, which must be done in iron kettles; the concentrated sulphuric acid does not dissolve iron. The silver and copper are dissolved with the formation of sulphurous acid, while the gold remains behind undissolved, as a brown powder. From the solution of silver and copper, the silver is precipitated by copper, and blue vitriol is obtained as a secondary product. This operation is called *refining*.

Formerly, with the same view, silver containing gold was dissolved in *nitric acid*, which does not dissolve the gold, though it does silver. In this case the remarkable fact was observed, that the silver was completely dissolved only when three fourths of silver were present to one fourth of gold (two thirds of silver, however, is an adequate proportion); hence the term *quartation*. If more than one fourth or one third of gold is contained in the alloy, the gold exerts a protecting influence upon the silver, so that the latter is not attacked and dissolved by the nitric acid.

The most simple mode of testing gold is to rub some of it off upon a black flint slate (touchstone), and apply to the mark a drop of aqua-fortis. If the gold is pure the yellow stroke remains unchanged, but if alloyed it partly disappears; if it is only an imitation of gold, for instance, tombac, it entirely dissolves.

385. *Gold and Acids.* — None of the common acids alone can dissolve gold, since this metal is in a high degree indifferent towards oxygen and acids. Chlorine is the only means of rendering it soluble (§ 152). Commonly the chlorine is obtained for this purpose by mixing muriatic with nitric acid; in this mixture, the well-known *aqua regia*, the gold dissolves completely by sufficient heating, and a brownish-yellow liquid is

obtained (*solution of gold*). By evaporating this solution to dryness, *terchloride of gold* ($Au\,Cl_3$) is obtained, as a brownish-red deliquescent salt. Metallic gold separates from it on exposure to the light, and likewise separates by introducing phosphorus, iron, zinc, and other metals, into a solution of it.

Experiments with Gold.

386. *Gilding.* — *Experiment a.* — Dip a dry test-tube into a diluted solution of gold, so as to moisten the bottom of it, and then heat it over the flame of a spirit-lamp; it will become gilded, — a proof that gold has only a very feeble affinity for chlorine, since it releases it at a mere gentle heat.

Experiment b. — Drop some of the solution of gold upon blotting-paper; let the paper dry, and then hold it by means of a wire over the flame of a spirit-lamp; you obtain finely-divided gold, mixed with the ashes of the paper as a coherent loose mass. If you rub this for some time upon a bright silver spoon, with a soft cork which has been dipped in salt water, the silver becomes gilt (*cold gilding*). There are other methods of gilding; — the *moist gilding*, in which the copper, brass, or silver articles are boiled with a very diluted solution of gold, to which some bicarbonate of soda, or cyanide of potassium, has been added; the *hot* or *quicksilver gilding*, by which these articles are smeared with a solution in mercury, and afterwards heated; the *galvanic gilding*, which is done in the same manner as the galvanic coppering. The *silvering* of metals is conducted on the same principle.

387. *Gold Powder.* — *Experiment.* — Drop into a weak solution of sulphate of iron some muriatic acid, and then some of the solution of gold; the liquid im-

mediately assumes a changeable dark and brownish color, but it appears of a beautiful blue color by transmitted light. On standing, a brown substance is deposited, which is gold in the state of minutest subdivision (*gold powder*). The green vitriol is at the same time converted into the sulphate of the sesquioxide of iron, and into sesquichloride of iron; decomposition is thus produced, by the great tendency of the protoxide of iron to pass over into the sesquioxide of iron. In this way the workers in gold precipitate that metal from liquids containing it. By triturating gold powder with oil of lavender, the color made use of by painters for gilding porcelain, glass, &c., is obtained.

388. *Gold and Oxygen.* — If the solution of gold is applied to the skin, or to any other organic substance, it imparts to it on drying a dark purple-colored stain, proceeding from the *protoxide of gold* ($Au\,O$). This protoxide of gold is also formed on the addition of the solution of gold to protochloride of tin (*purple of Cassius*). That the most beautiful purple color is produced by this on glass and porcelain has already been mentioned, under the head of tin (§ 322). Gold may be recognized in its solutions by salt of tin. Teroxide of gold ($Au\,O_3$) is of a brownish-black color, and comports itself like an acid towards bases. It combines with ammonia, like the oxide of silver, forming fulminating gold.

389. *Sulphuret of Gold.* — When sulphuretted hydrogen is added to a solution of gold, a black precipitate of *sulphuret of gold* is produced, which is soluble in sulphuret of ammonium. Gold cannot be united directly with sulphur, by fusing them together.

PLATINUM (Pt).

At. Wt. = 1232. — Sp. Gr. = 21.5.

390. Platinum, a metal of still greater density than gold, was brought in the last century from America, where it was found, in the form of small, flattened grains, mixed with the sands from which the gold was washed. It received the name *platinum*, derived from the Spanish word *plata*, silver, on account of its resemblance to silver in color and ductility. It was afterwards found also in the sand of the Ural Mountains, in compact *lumps*, from the size of a flax-seed to that of a man's fist. Platinum, like gold, is a *noble* metal, and, like iron, is *tenacious*, *ductile*, and *can be welded*, and is, moreover, infusible at the strongest furnace heat. These properties have rendered platinum an invaluable metal to the chemist. Sulphuric and hydrofluoric acids can be distilled in platinum retorts, aqua-fortis can be boiled in platinum capsules, and substances can be subjected to the strongest white heat in platinum crucibles, or on platinum foil or wire, without the platinum articles being broken or melted. It is only necessary to be careful that no metal be heated with platinum, as a fusible alloy might thus be formed, and the platinum apparatus be melted or broken even at a moderate heat. The value of platinum is intermediate between that of gold and silver, and in Russia it has been coined into money. It is less adapted for articles of luxury than either of these two metals, its color not being of a pure, but of a grayish white, and its lustre far inferior to that of silver. It can be fused by the oxy-hydrogen blow-pipe, or by the galvanic battery.

391. Platinum, like gold, is dissolved by heating it for a long time with aqua-regia; and a dark-brown so-

lution of chloride of platinum = $Pt\ Cl_2$ is obtained (*solution of platinum*). A small quantity of this solution can easily be prepared from one or several pieces of spongy platinum, such as are employed in the Döbereiner hydrogen-lamp.

Experiments with Platinum.

392. *Finely divided Platinum.* — *Experiment.* — Add a few drops of a solution of platinum to a solution of sal ammoniac; the two salts will combine together, forming a yellow insoluble double salt, which is called *chloride of platinum and ammonium.* After settling, decant the supernatant liquid; let the precipitate partly dry in a dish, so that it forms a moist paste; affix it to a platinum wire, several times bent, and hold it in the flame of a spirit-lamp. The sal ammoniac flies off, but the platinum remains behind as a gray, loosely coherent, porous mass, the so-called *spongy platinum.* When held in hydrogen, it becomes red-hot, and inflames the gas (§ 85). The porous platinum acts on gases in the same manner as the pump of an air-gun, only far more rapidly and vigorously; it absorbs them, and condenses them so powerfully together into its pores, that the atoms of two different gases often approach each other sufficiently near to combine together chemically. As hydrogen and oxygen are in this instance compelled to unite, so the spongy platinum can force many other gases, which will not directly combine with each other, to enter into combination.

Pure platinum is commonly prepared from spongy platinum, which is heated to whiteness and then quickly compressed by strong pressure. A compact mass is thus obtained, which, on being again heated, may be hammered out into uniform pieces, and afterwards rolled into plates, drawn out into wire, or moulded into crucibles, capsules, &c.

By proper chemical means, platinum may be divided still more minutely than in the case of spongy platinum; it is then obtained in the form of a *delicate black powder*, which possesses, in a still higher degree than spongy platinum, the power of condensing gases into its pores; it is called *platinum black*. If some alcohol be dropped upon this platinum black, ignition takes place, with an almost instantaneous conversion of the alcohol into acetic acid. The reason of this change is to be sought for in a combination of the alcohol with the oxygen of the air, which is effected by means of the porous platinum black.

393. *Experiment.*—If you perform the experiment described in § 386 with a solution of platinum, you obtain a coating of metallic platinum upon the glass. The combination between this metal and chlorine is likewise so feeble, that heat alone is able to destroy it.

394. *Experiment.*—Dissolve one of the salts of potassa, and add to it some drops of solution of platinum; here also, as in § 392, a yellow insoluble precipitate is formed, consisting of potassium, platinum, and chlorine. The solution of platinum serves, therefore, as a test for the salts of potassa (and salts of ammonia). The solution of platinum is precipitated black by sulphuretted hydrogen (sulphuret of platinum).

Platinum forms with oxygen a *peroxide* and a *protoxide;* likewise with chlorine, a *perchloride* and a *protochloride.*

Palladium, Iridium, Rhodium, and Osmium.

395. These four metals are, as it were, the satellites of platinum; they are always found in small quantities

in the crude platinum sand, and are obtained on the purification of the latter, by a somewhat elaborate process. They also have the character of noble metals.

RETROSPECT OF THE SECOND GROUP OF THE HEAVY METALS.

1. The metals lead, bismuth, copper, mercury, silver, gold, and platinum do not possess the power of decomposing water, that is, of abstracting its oxygen, like the metals of the first group; therefore, concentrated acids must be employed for their solution.

2. Their lowest degrees of oxidation are bases, while their higher degrees comport themselves sometimes like bases, sometimes like acids.

3. These metals most frequently occur in nature uncombined, or as sulphurets, rarely as oxides.

4. They have a greater specific weight than the metals previously described; it varies from 8.8 to 21.5. (That of iridium is indeed 23.0).

5. They are all precipitated as *black sulphurets* by sulphuretted hydrogen and sulphide of ammonium; the sulphurets of gold and platinum are redissolved by the latter reagent.

6. The metals mercury, silver, gold, and platinum, together with the last-named associates of platinum, are called *noble metals*, because they remain bright in the air or in water. When oxidized by other means, by acids, for instance, the oxides may be again resolved merely by heat into metal and oxygen. This is effected with the ignoble metals only by the addition of a reducing agent, as by charcoal.

THIRD GROUP OF HEAVY METALS.

TUNGSTEN, MOLYBDENUM, TELLURIUM, TITANIUM, TANTALUM, VANIDIUM, NIOBIUM, PELOPIUM.

396. These metals occur only as chemical rarities, and have not yet found any useful application. Their highest degrees of oxidation are clearly defined *acids*. The first two are the most common, as they are sometimes dug out from tin mines,—tungsten as wolfram ore, and molybdenum as sulphuret of molybdenum, or molybdate of lead.

CHROMIUM (Cr).

At. Wt. = 328.—Sp. Gr. = 6.

397. Chromium has only been known within a few decades, and already several of its combinations have become common and valued articles of commerce. The cause of this rapid extension is owing to the beautiful color of many of the preparations of chromium, on account of which they are excellently adapted for pigments. This also has given rise to the name *chromium* (color).

The most important ore of chromium, *chromate of iron*, an insignificant looking black mineral, is mostly obtained in North America, and is manufactured into a red salt, which consists of *potassa and chromic acid*. The other compounds of chromium are prepared from this salt.

Fig. 159.

398. *The Red Chromate or Bichromate of Potassa* ($KO, 2\,CrO_3$) is an *acid salt*, for it contains two atoms of chromic acid and one atom of potassa, and commonly occurs in beau-

tiful tabular or prismatic crystals. Rub an ounce of it with ten ounces of water; it will dissolve in it, forming an orange-yellow solution.

Experiment. — Add to one half of this solution a dram of pure carbonate of potassa, and concentrate by evaporation the liquid, which has become of a clear yellow color; on cooling, yellow crystals will be deposited. These consist of *neutral chromate of potassa* ($K\,O,\ Cr\,O_3$). The potassa of the carbonate of potassa has, while the carbonic acid escaped, combined with the second atom of chromic acid. If nitric acid is added to a solution of the yellow salt, the liquid becomes darker, and on evaporation red crystals are obtained, mixed with crystals of nitre. It is obvious that the nitric acid has abstracted half of the potassa.

399. *Chromate of Oxide of Lead* ($Pb\,O,\ Cr\,O_3$). — *Experiment.* — Add to a portion of the solution of the red salt a solution of sugar of lead, as long as there is any precipitate; this precipitate, when washed and dried, is the well-known *chrome yellow*, and is the richest and most vivid of all the yellow pigments. By mixing it with white substances, — for instance, chalk, talc, clay, gypsum, &c., — numerous other shades of yellow are obtained, as new-imperial, king's, Paris, &c., yellow; but by mixing it with Prussian blue, the well-known cheap green pigments are obtained, called olive green, Naples green, green cinnabar, &c.

Experiment. — If chrome yellow is stirred up with water and heated with some carbonate of potassa, it passes into *chrome orange*, which is also used as a painter's color. This contains somewhat *less* chromic acid than the chrome yellow; accordingly, the potassa abstracts from the chrome yellow a portion of the chromic acid, which is rendered apparent by the yellow color of the liquid filtered off from the chrome orange.

By fusing with nitre, still more, even a half, of the chromic acid may be withdrawn from the chrome yellow; in this way we obtain a beautiful red color, almost rivalling that of cinnabar, *chrome red*, or basic chromate of oxide of lead ($2\ PbO, CrO_3$). Thus we see that the colors of the combinations of lead comport themselves inversely to those of the combinations of potassa; the chrome yellow passes into orange and red by *abstracting* chromic acid, while yellow chromate of potassa, on the contrary, becomes red by *adding* more chromic acid, or, what amounts to the same, by withdrawing potassa.

Experiment. — Chrome yellow has obtained also a very important application in the dyeing and printing of yarns and fabrics. First dip a piece of cotton into a solution of chromate of potassa, then, after it has become dry, into a solution of sugar of lead; it is dyed *yellow*. If you now boil a little quicklime with water in a vessel, and then dip the cotton dyed yellow into it for a few moments, it will acquire a *reddish-yellow* color, because the lime, just like the carbonate of potassa, abstracts some chromic acid from the chrome yellow. It is scarcely necessary to explain any further why chrome yellow cannot be used for painting the walls of apartments. Salts of zinc and baryta are precipitated yellow, salts of suboxide of mercury a brick-red, and salts of silver a purple-red, by chromate of potassa.

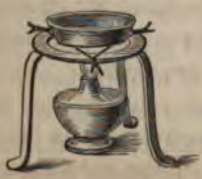
400. *Sesquioxide of Chromium* (Cr_2O_3). — *Experiment.* — Boil some chrome yellow in a test-tube with muriatic acid; it becomes white, and the liquid green; the white residue consists of muriate of oxide of lead (chloride of lead), but the liquid holds in solution *muriate of the sesquioxide of chromium* (sesquichloride of chromium). A piece of moistened litmus-paper, or of paper smeared

with ink, introduced into the tube during the boiling, is bleached, as *chlorine gas* escapes at the same time. The process is analogous to that of the evolution of chlorine from black oxide of manganese, or from aqua-regia; the chromic acid gives up half its oxygen, and becomes green *sesquioxide of chromium*, but the oxygen, becoming free, abstracts from a portion of the muriatic acid its hydrogen, and liberates its chlorine. Decant the green solution, dilute it with water, and add to it ammonia; the ammonia combines with the muriatic acid, and the sesquioxide of chromium is precipitated as a *hydrate* having a bluish-green color. Dried and ignited, it becomes a dark green *anhydrous oxide*. A fine green is produced by it on porcelain and glass; accordingly it is esteemed as a valuable vitrifiable pigment.

Experiment. — The ease with which chromic acid gives up half of its oxygen may also be shown with chromate of potassa. Dissolve in a test-tube a few grains of red chromate of potassa in warm water; add a few drops of sulphuric acid, and heat the solution still more strongly. If you now add a little sugar or some drops of alcohol to it, a brisk ebullition ensues, and the color of the solution is changed from red to green; sulphate of potassa and sulphate of sesquioxide of chromium are now contained in the liquid.

401. *Chromic Acid* ($Cr\,O_3$). — *Experiment.* — Reduce to powder half an ounce of red chromate of potassa, put it into a porcelain dish, and then add half an ounce of water and half an ounce of sulphuric acid, and heat the whole, with constant stirring, for five minutes. If a drop of it is

Fig. 160.



put on blotting-paper, it effervesces, and changes its yellowish-red color to green. When the vessel is entirely cold, add an ounce of cold water to the thick saline mass, stir it a few minutes, and then carefully decant the liquid into a beaker-glass. What remains in the dish is sulphate of potassa; but we have in the liquid a solution of chromic acid, which is precipitated as a red mass by adding to it from one and a half to two ounces of common sulphuric acid. Cover the beaker-glass with a small board, set it aside for twenty-four hours, and then *carefully* pour off the supernatant acid into a glass vessel, and transfer the red paste remaining behind to a new brick, by which the fluid portion is completely absorbed. After twenty-four hours, during which time the precipitate is kept covered with a dish, you obtain the chromic acid, as a crystalline, red powder, which must be scraped off from the brick with a glass rod, and put into a wide-mouthed phial, provided with a glass stopper. The following experiments will illustrate the extreme ease with which this highly interesting body decomposes into sesquioxide of chromium and oxygen.

Experiment a. — Rinse out a tumbler with strong alcohol, then throw into it a few grains of chromic acid; the alcohol which remains adhering to the tumbler will combine with half the oxygen of the chromic acid, with such energy, that it ignites and instantaneously bursts into flame. The change which the alcohol has hereby undergone is at once revealed by the odor, similar to that of the vinegar apartments; in the latter, the alcohol contained in the brandy, beer, &c. slowly imbibes oxygen from the air, and is converted into vinegar; in the present case this conversion is instantaneously produced by the oxygen of the chromic acid.

Experiment b.— Mix in a small mortar as much chromic acid as can be taken up on the point of a knife with about one quarter as much of powdered camphor (without pressing upon it strongly), and then let some drops of alcohol fall from a considerable height into the mortar; instantaneous ignition and deflagration ensue, almost as if you were burning gunpowder. The residue in the mortar presents, after the decomposition, the appearance of an elegant green mossy vegetation; it consists of sesquioxide of chromium, which at the moment of its formation was scattered by the burning camphor fumes, and was thereby most delicately subdivided.

It is obvious from this action, that chromic acid may be classed under one and the same category with nitric acid, chloric acid, manganic acid, hyperoxide of manganese, hyperoxide of lead and chlorine (and the finely divided platinum); it possesses in a high degree the property of forcing other bodies into a combination with oxygen.

ANTIMONY, STIBIUM (Sb).

At. Wt. = 1613.—Sp. Gr. = 6.7.

402. *Antimony* has a lamellar crystalline texture, and a white metallic lustre, like bismuth, but without the red tint of the latter; it far exceeds it in brittleness, for it may be easily rubbed to powder in a mortar. The soluble preparations of antimony are undisguised enemies to animal life, and consequently the stomach exerts itself to remove from the body all such compounds introduced into it. This is effected by *vomiting*, and for the very reason of its emetic properties, antimony has become a very important medicine.

403. *Oxide of Antimony* ($Sb\,O_3$). — *Experiment.*—

Antimony does not alter in the air, but if a piece of it is heated on charcoal before the blow-pipe, it soon melts, and burns with a white flame, forming an *oxide*, which partly escapes as a white vapor, and is partly deposited as a coating on the charcoal. If you let the melted metallic globule slowly cool, the oxide condenses into crystals, which form around the metal an *espalier* of white points. When thrown into a paper capsule, the white glowing globule will burst into a multitude of small spheroids, which skip about for some time, leaving in their trail a pulverulent oxide. Antimony generally contains traces of arsenic; hence the smell, like that of garlic, which almost always accompanies its fusion.

404. *Antimonic Acid* ($Sb\,O_5$). — If antimony is treated with nitric acid, it takes up two more atoms of oxygen, and becomes *antimonic acid*, a yellowish powder, insoluble in water and acids. At a glowing heat one atom of oxygen is expelled from this, and a compound of antimonic acid with oxide of antimony remains behind, which may be regarded as *antimonious acid* ($Sb\,O_4$). It is not volatile at a glowing heat, and has the property of imparting to glass and porcelain a yellow and orange color.

Experiment. — If some powdered antimony be heated with *nitric acid*, the same thing occurs as with tin; namely, the metal is converted into a white powder, which consists of a mixture of both degrees of oxidation, antimonic acid and oxide of antimony. A similar process takes place by mixing powdered antimony with nitre, and throwing the mixture into a glowing hot crucible; in this case only antimonic acid is formed, which remains behind combined with the potassa. The *antimoniate of potassa* may be dissolved by boiling in water, and is then used as a test for the salts of soda, the antimonic acid forming with the soda a very sparingly soluble salt.

405. *Chloride of Antimony.* — Antimony is dissolved only with great difficulty by muriatic acid; a solution is more readily obtained by employing sulphuret of antimony instead of metallic antimony.

Experiment. — Put half an ounce of sulphuret of antimony into a capacious flask; pour over it two ounces and a half of muriatic acid, and heat it in a sand-bath, at first moderately, but afterwards to boiling; the sulphuretted hydrogen, escaping in large quantities, is conducted either into water or into milk of lime, by which it is completely absorbed. The sulphuret of antimony and the muriatic acid are converted into sulphuretted hydrogen and *chloride of antimony* (muriate of oxide of antimony). After several days' repose, decant the clear liquid; it contains chloride of antimony in solution, and was formerly called *butter of antimony.* By continuously rubbing some drops of it upon an iron plate, a very strongly adhering coating of oxide of iron is produced, which imparts to the iron a brown appearance, and renders it less liable to rust. In this way the well-known color (browning) is given to gun-barrels.

The liquid obtained as a secondary product, filtered from the milk of lime, is to be regarded as hydrated *sulphuret of calcium;* it has the property of rendering hair so loose in the skin, that it may easily be pulled out, as will appear if a piece of calf-skin is softened in it for some time.

Experiment. — By pouring one ounce of the liquid muriate of antimony into ten ounces of hot water, a decomposition and turbidness are produced, as in the case of the solution of bismuth; the precipitate is *oxide of antimony* combined with a little muriatic acid. Wash it several times with water, by settling and decanting the liquid, and then digest it for an hour with a solution of a quarter of an ounce of carbonate of soda in two ounces of hot water, whereby the muriatic acid is completely removed. The precipitate, being again washed, yields, when dry, a white powder of oxide of antimony. The same preparation is thus obtained in a moist way, as by igniting the metallic antimony (§ 403).

406. *Tartar Emetic* ($KO, \bar{T} + SbO_3\bar{T} + 2HO$).—*Experiment.*—Boil in a porcelain dish two ounces of distilled water, and during the boiling stir in a mixture of one dram of oxide of antimony, and one dram of cream of tartar. When the liquid is half boiled away, filter it while boiling, and pour one half of it into one ounce of strong alcohol, but set the other half aside. In both cases you obtain a white salt, *tartar emetic;* in the latter case in the form of crystals, but in the former as a fine powder, because tartar emetic is insoluble in alcohol, and consequently is precipitated by it from its solutions. The process in this case is a very simple one. Cream of tartar is an acid salt, that is, a combination of tartrate of potassa with free tartaric acid; this free tartaric acid combines with the oxide of antimony. Thus we obtain tartrate of potassa and tartrate of oxide of antimony, which unite together, forming a double salt, tartar emetic. The name indicates the medicinal application of this double salt; it is the most usual means of inducing vomiting. One grain of it, dissolved in half an ounce of Teneriffe or Sherry wine, forms the well-known *wine of antimony.* One ounce of tartar emetic requires fifteen ounces of cold water for solution.

407. *Sulphuret of Antimony.* — *Experiment.* — Add some sulphuretted hydrogen to a solution of tartar emetic in water: an *orange-colored precipitate* of sulphuret of antimony ($Sb\ S_3$) is obtained, which becomes darker on drying. Thus the combination of antimony may be very well recognized, as no other metal yields a sulphuret of this color.

We most frequently find antimony in nature having this composition; but the native sulphuret of antimony has quite another color, namely, *steel-gray*, and in other respects likewise a very different exterior condition, as it occurs in heavy compact masses, which on the fractured surface appear as if they were composed of small shining needles or points. On account of this appearance, it has received the name of *prismatoidal antimony glance.* It melts even in the flame of a candle, and hence may be obtained from the different sorts of rock with which it is associated, merely by liquation. When pulverized, it forms a black gray shining powder, which is employed by the farmer as a familiar remedy in the diseases of domestic animals. It is commonly, but erroneously, called *antimony*, by which term *sulphuret of antimony* is implied.

Experiment. — Boil a small quantity of pulverized gray sulphuret of antimony with a solution of potassa, let it settle, and add an acid to the decanted liquid: a brownish-red precipitate is produced, likewise sulphuret of antimony, which was dissolved by the potassa. This sulphuret of antimony (containing an oxide), which in the apothecary's shop is called *Kermes mineral*, is much more finely divided (§ 129) than the gray, and thereby acquires the red color; the division is still greater in the orange-colored sulphuret, prepared from the tartar emetic.

These three combinations, the orange, the red, and gray sulphurets of antimony, have quite a similar composition; they are one and the same body, only existing in different *isomeric* states.

A still higher sulphuret of antimony ($Sb\ S_5$) occurs in the pharmacopœias, under the name of the *golden sulphuret*, as an important medicine; it has an orange color, and corresponds in its constitution to antimonic acid, as the gray or red sulphuret corresponds to the oxide of antimony.

For *Antimoniuretted Hydrogen*, see § 418.

408. *Preparation of Antimony.* — In order to separate metallic antimony from the sulphuret, it is only necessary to fuse it with iron, which has a greater affinity for the sulphur, and unites with it, forming sulphuret of iron. On cooling, the heavy metallic antimony settles at the very bottom.

409. *Alloys of Antimony.* — Of the alloys which antimony forms with other metals, that with lead, from which types are cast, deserves especial notice. Lead alone is much too soft to be employed for this purpose, but if from an eighth to a twelfth part of antimony is mixed with it, it acquires such a degree of hardness, that types cast from it may be used for printing many thousand times without losing their distinctness.

ARSENIC, ARSENICUM (As).

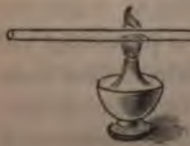
At. Wt. = 937. — Sp. Gr. = 5.7.

410. *Poisonous as arsenic*, is almost a proverbial expression, and it shows, in this respect, at least, that arsenic is well known, and in sufficiently bad repute. In fact, it is placed among the *metallic poisons*, and a very small quantity of it produces a fatal effect, unless antidotes

are quickly administered. Happily, in recent times a means has been discovered, in the *hydrated sesquioxide of iron* (*iron-rust*), by which most of the combinations of arsenic may be rendered, even in the stomach, insoluble, and thereby harmless. Before this remedy and the aid of the physician can be procured, it is well in cases of poisoning by arsenic, as in cases of poison generally, to administer milk, white of eggs, soap suds, or sugar. On account of the dangerous effects of arsenic, the *greatest care* must be taken, in experimenting with it, not to inhale its dust or vapor; the vessels that contain it must also be most carefully washed, and the water used for this purpose should be emptied into some place not accessible to domestic animals.

411. *Metallic Arsenic.* — Metallic arsenic is not unfrequently found in the earth, as a lead-gray ore, of strong metallic lustre. The artificially prepared metallic arsenic, which soon tarnishes and assumes motley colors in the air, and finally falls into a coarse gray powder, is kept on hand in the apothecaries' shops, under the name of fly-poison. If boiled with water, the film of oxidized arsenic dissolves, and a very poisonous liquid is obtained (fly-poison). A fresh film of oxide is produced upon the metal which remains, and thus is very easily explained why, after a time, a new poisonous solution can again be prepared from it, without any perceptible decrease of the original powder.

Fig. 161.



Experiment. — Put a piece of arsenic of the size of a millet-seed into a glass tube, hold the latter by one end, and heat it; the arsenic volatilizes at 180° C., and deposits itself on the upper portion of the tube as a *brilliant black mirror; the smell of garlic*, peculiar to the fumes of arsenic, being at the same time given off. These two tests are employed as very accurate for detecting the presence of arsenic in other bodies. Phosphorus, when exposed to the air, emits, likewise, the odor of garlic. If this indicates a similarity in these two bodies, the resemblance is rendered still more striking, since arsenic behaves very much like phosphorus in its combinations with other substances.

412. *White Arsenic, or Arsenious Acid* ($As\ O_3$).

Experiment. — Let the arsenical mirror obtained in the above experiment be heated once more, but in an *open* tube; it is converted into a vapor, which condenses on the colder parts of the tube, partly in small white crystals, partly as powder. Before the magnifying-glass these crystals appear as four-sided double pyramids (octahedrons); their constituent parts are arsenic and oxygen, and they are called *arsenious acid*, *white arsenic*, or ratsbane. When arsenic is spoken of in a popular sense, the white arsenic is always implied. It is obtained on a large scale, — *a.*) as a secondary product in the roasting of tin, silver, and cobalt ores; *b.*) as a principal product, by heating arsenical ores with access of air (in the arsenical furnaces in Saxony and Silesia). In both cases the arsenious acid passes off as vapor, with the smoke, which must therefore be conducted through long, horizontal chimneys, till it cools, and the arsenious acid condenses as a powder (*white arsenic*). White arsenic is often re-sublimed in some appropriate apparatus, and is then obtained as *amorphous* arsenious acid, in solid transparent pieces. These after a time become opaque and *milk-white*, like porcelain, without changing their constitution; another example that, even in solid bodies, atoms can alter their relative situations (§ 280).

Arsenious acid is especially distinguished from the other metallic oxides by its solubility in water, which, indeed, is not very great, since one grain of it requires fifty grains of cold water, or from ten to twelve grains of boiling water, for solution; but it is sufficiently soluble to render these solutions exceedingly dangerous poisons. White arsenic is generally employed for killing rats, moles, and other troublesome house or field animals; for this purpose colored arsenic only should be purchased, as the white arsenic looks very much like sugar or flour, and might easily be mistaken for it. In order to prevent its being carried off, it is best to strew powdered arsenic over broiled rinds of pork, or broiled fish, nailed upon boards. If the poison is put in stables, the fodder-troughs should be carefully covered over, that the poisoned rats may not vomit the poison into them.

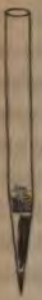
Arsenious acid, like chloride of mercury, prevents the decay of organic substances; therefore the skins of animals intended for shipping are rubbed with arsenic upon the flesh side.

Arsenious acid readily gives up its oxygen in the heat to other bodies; for this reason it is added by glass-makers to melted glass, to convert its black or green color into yellow. It acts like black oxide of manganese (§ 297); namely, it oxidizes the protoxide into sesquioxide of iron. A solution of white arsenic and mercury in nitric acid is used by hat-makers to remove the shining smooth coating from the fur of hares.

413. *Reduction of White Arsenic.*

Experiment. — Draw out a glass tube into a point,

Fig. 162.



introduce into it a very little arsenious acid, and put upon it a splinter of charcoal; then heat the tube to redness in the flame of a spirit-lamp, first at the place where the coal lies, and afterwards at the pointed extremity of the tube; the glass becomes coated on the inside above the coal with a black *metallic mirror*, because the oxygen is withdrawn from the vapors of the arsenious acid while they pass over the glowing coal. This is one of the surest methods of detecting small quantities of arsenic.

414. *Combinations of White Arsenic with Bases.*

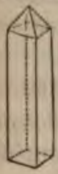
Experiment. — If ten grains of arsenious acid and twenty grains of carbonate of potassa are heated with half an ounce of water, the arsenic very readily dissolves, and a solution of *arsenite of potassa* is obtained.

a.) Add gradually to one half of this liquid a solution of fifteen grains of blue vitriol in half an ounce of hot water; a yellowish-green precipitate soon subsides, which, on drying, passes over into a dark-green. This *arsenite of oxide of copper* occurs in commerce under the name of *Scheele's green.*

b.) The other half of the solution is likwise mixed in a flask with a solution of fifteen grains of blue vitriol in half an ounce of water, and then acetic acid (concentrated vinegar) is added as long as effervescence continues; the whole is then boiled for five minutes, after which the flask is put in a basin of hot water, that the cooling may take place *very slowly.* We obtain in this way, after twenty-four hours' repose, a double compound of arsenite and acetate of copper, which, on account of its splendid green color, is extensively used as a pigment. Of its numerous names, those most known are *Schweinfurth green, vert de mitis*, and *Vienna green. This color is as poisonous as white arsenic;* hence extreme caution in the use of it cannot be too strenuously urged; it may even prove dangerous as a green paint for rooms, since, under some circumstances, volatile combinations of arsenic are formed from it, and unite with the air.

415. *Arsenic Acid* ($As\,O_5$). — If arsenious acid is boiled with nitric acid, it takes from the latter two additional atoms of oxygen, and becomes *arsenic acid*. The same acid is obtained, combined with potassa, by fusing together arsenious acid and nitre. The *biarseniate of potassa* thus produced, which crystallizes in beautiful four-sided prisms, has hitherto been consumed in immense quantities in calico-printing, not so much to produce colors as to prevent their formation on certain points of the texture.

Fig. 163.



416. *Sulphuret of Arsenic.* — *Experiment.* — Dissolve some grains of arsenious acid in boiling water, and add to the solution sulphuretted hydrogen; a precipitate of *yellow sulphuret of arsenic* ($As\,S_3$) is formed, three atoms of sulphur replacing three atoms of oxygen. In this way arsenic may easily be detected in liquids, and separated from them; the salts of cadmium and oxide of tin are the only ones, except arsenic, which give a yellow precipitate with sulphuretted hydrogen.* Sulphuret of arsenic is redissolved by sulphuret of ammonium.

Sulphuret of arsenic also occurs native, and is called *orpiment*, or king's yellow, and was formerly used as a yellow pigment, but it is earnestly advised never to employ this color in the painting of rooms, as olves upon lime walls an exceedingly poisonous *arseniuretted hydrogen*). A sort of yellow arsenic, ig the color of yellow wax or porcelain, is also pre- l in arsenical works by the sublimation of white iic with a little sulphur; this consists principally of iious acid, and contains but a small quantity of iuret of arsenic.

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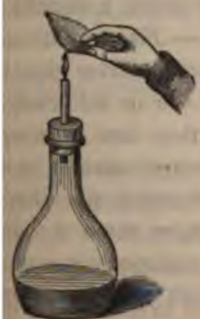
* The salts of antimony are precipitated of an orange-yellow color by *sulphuretted* hydrogen.

combination of arsenic with one atom less of sul- ($As\ S_2$), which is sometimes transparent like ruby-olored glass, and sometimes opaque like brownish- orcelain, has received the name *Realgar*, or *red sul- et of arsenic.*

eparation of Arsenic. — Arsenic is most frequently d combined with sulphur and iron, as *arsenical py-* Most of the white arsenic is prepared from this by roasting it in a reverberatory furnace, and, as dy mentioned, condensing in poison towers the s containing arsenious acid. The iron and sulphur xidized at the same time with the arsenic; but the zed iron remains behind, and the oxidized sulphur) escapes with the smoke into the air.

7. *Arseniuretted Hydrogen Gas* ($As\ H_3$). — *Experiment.* — Introduce into a small flask diluted sulphuric acid and some pieces of zinc, and let the hydrogen which is evolved escape through a tube drawn out to a point, and *after some time* ignite it (§ 85); you obtain in this manner a hydrogen-lamp. If you hold a glazed porcelain capsule for some minutes in the flame, you will perceive upon it only a circle of

Fig. 164.



small drops of water, which form during the combustion of the hydrogen, and condense on the cold portion. If you now dip a piece of wood into Schweinfurth green, so that only a little of it shall remain adhering to the wood, and introduce it into the flask, the flame, after the gas has been rekindled, will present a bluish-white appearance, and will deposit on the porcelain held in it a *black* or *brown smooth spot* (mirror); this mirror is metallic arsenic. Like sulphur and phosphorus, arsenic also will combine with hydrogen, forming a kind of gas, which, in company with the free hydrogen, escapes and burns. The flame is cooled by a cold body below the temperature which arsenic requires for burning; hence the latter condenses on the porcelain, just in the same way as carbon or soot is deposited on it when held in the flame of a candle. The carbon separates as a light, pulverulent body, arsenic as a coherent mirror. This incredibly sensitive test is called, after its inventor, *Marsh's arsenical test.* It follows from the previous remarks, that care should be taken not to inhale the escaping gas, particularly the unburnt gas; but here more than ordinary caution is necessary, as arseniuretted hydrogen is a *most poisonous gas*, and one to which some chemists have already fallen a sacrifice.

418. *Antimoniuretted Hydrogen.* — *Experiment.* — Repeat the same experiment, substituting tartar emetic for Schweinfurth green; black spots are in this case also deposited on the porcelain, but they are darker, and often have a sooty appearance; they consist of *metallic antimony.* To distinguish spots of antimony with certainty from spots of arsenic, drop upon them a solution of chloride of lime; the spots of antimony remain unchanged, while the arsenical mirrors dissolve immediately.

Antimony and *arsenic* are the only metals which combine with *hydrogen;* they comport themselves in this respect like the metalloids; they may be regarded as the link, the bridge, which joins the territory of the non-metallic bodies or metalloids with the metals.

RETROSPECT OF THE THIRD GROUP OF THE HEAVY METALS.

1. The metals chromium, antimony, and arsenic, together with the previously-mentioned rarer metals, cannot decompose water; therefore concentrated acids must be employed for their solution.

2. Their lower degrees of oxidation comport themselves sometimes like bases, and sometimes like acids, but the higher only as *acids.*

3. These metals occur most frequently in nature combined with sulphur.

4. Antimony and arsenic are precipitated from their solutions as sulphurets by sulphuretted hydrogen, but are redissolved by sulphuret of ammonium. Chromium is not converted into a sulphuret by sulphuretted hydrogen.

5. Antimony and arsenic can, like the metalloids, unite with hydrogen, forming gaseous compounds.

RETROSPECT OF ALL THE METALS.

Metals.

1. All metals have a peculiar *lustre*, are *opaque*, and the best *conductors* of heat and electricity.

2. Most of the metals will *crystallize* on cooling slowly (most commonly in cubes).

3. All the metals are *fusible*, but at very different degrees of heat; many of them, also, may be volatilized.

4. All metals can combine with *oxygen*, *sulphur*, and *chlorine*.

5. They likewise combine with each other when they are fused together (alloys).

Metallic Oxides.

6. Most of the metals form *basic oxides* with oxygen. Almost all the metallic oxides are insoluble in water.

7. Many metals possess one known *degree* only of *oxidation*, but most of them have two, some, indeed, three, four, and even five degrees of oxidation. The highest comport themselves as acids.

8. Metallic oxides may be *prepared* from the metals:—

- *a.*) By exposure to the moist air.
- *b.*) By heating with access of air.
- *c.*) By decomposition of water at the ordinary temperature.
- *d.*) By decomposition of water at a red heat.
- *e.*) By decomposition of water with the aid of an acid, and precipitation by a strong base.
- *f.*) By treating with concentrated acids, and precipitation by a strong base.
- *g.*) By heating with nitre or chlorate of potassa.

9. The metallic oxides may be *deoxidized* or *reduced* to metals:—

- *a.*) By mere heating (noble metals).
- *b.*) By heating with charcoal.
- *c.*) By heating in hydrogen gas.
- *d.*) By a more electro-positive metal (having a greater affinity for oxygen).
- *e.*) By the galvanic current.

Metallic Sulphurets.

10. The sulphurets of the light metals are soluble in water, those of the heavy metals are, on the contrary, insoluble.

11. A metal has commonly as many degrees of sulphuration as of oxidation.

12. The metallic sulphurets may be *prepared,* —

a.) Directly by rubbing or melting together sulphur and a metal, or by heating the metal in the fumes of sulphur.

b.) By adding sulphuretted hydrogen or sulphuret of ammonium to a metallic oxide or salt.

c.) By heating metallic sulphates with charcoal.

13. Sulphur may be expelled from the metallic sulphurets, —

a.) By heating them with access of air (roasting).

b.) By a more electro-positive metal.

c.) By heating in steam.

d.) By heating with strong acids.

Metallic Chlorides.

14. Most of the metallic chlorides may be crystallized, and are soluble in water.

15. As a general rule, a metal combines in as many proportions with chlorine as it has degrees of oxidation.

16. Metallic chlorides *are prepared,* —

a.) By bringing the metals or metallic oxides into contact with chlorine.

b.) By dissolving metals in muriatic acid.

c.) By dissolving metals in aqua-regia.

d.) By double elective affinity, on mixing metallic chlorides with oxygen salts.

17. Chlorine may be *separated* from the metals, —
  - a.) By mere heating (the noble metals only).
  - b.) By heating in hydrogen gas.
  - c.) By a more electro-positive metal.
  - d.) By a stronger acid, for instance, sulphuric acid.

The Oxygen Salts.

18. Every acid usually forms a salt with every metallic base; hence, there is an infinite number of salts.

19. Suboxides must receive oxygen and hyperoxides part with it before they can combine with acids.

20. Most of the salts may be crystallized, sometimes with and sometimes without water of crystallization.

21. The salts behave very differently towards water; some dissolve in it very easily, others with difficulty, and others not at all.

22. Salts may be *prepared,* —
  - a.) By exposing metals to the air.
  - b.) By dissolving them or their oxides in acids.
  - c.) By decomposition of the metallic sulphurets with acids; also by a spontaneous weathering of the metallic sulphurets.
  - d.) By mutual decomposition by means of predisposing simple or double elective affinity.

23. Many of the salts, by mere heating, lose their acids, which either escape (carbonic acid), or burn up (organic acids).

24. The salts, like the oxides, may be reduced to metals. If this is effected by ignition with charcoal, it is necessary to superadd a strong base (carbonate of soda, lime), which attracts the acid from the salt.

Occurrence of Metals in Nature.

25. The metals principally occur native in five forms,

viz.:—1. uncombined, or *massive*; 2. combined with *sulphur*, as pyrites, glance, and blende; 3. with *arsenic*, as arsenical metals; 4. with *oxygen*, as oxides; 5. with *oxygen* united with *acids*, as salts.

Of the best known metals, the following occur the most frequently:—

1. *Pure.*	2. *As Sulphurets.*	3. *As Arsenical Metals.*
Gold,	Lead,	Cobalt,
Platinum,	Antimony,	Nickel,
Silver,	Copper,	Silver,
Bismuth,	Silver,	Iron.
Mercury,	Mercury,	
Arsenic.	Arsenic,	
	Iron,	
	Zinc.	

4. *As Oxides.*	5. *As Salts.*
Manganese,	Potassium and Sodium,
Tin,	Barium and Strontium,
Iron,	Calcium and Magnesium,
Chromium,	Aluminium,
Zinc,	Zinc and Iron,
Uranium,	Lead and Copper.
Copper.	

Classification of the more common Chemical Elements.

It is very difficult so to classify the chemical elements,—so to bring them, as it were, into rank and file,—as to present at the same time a correct idea of their external and internal properties, and of their affinities for each other. In the following scheme, the two elements which are the most dissimilar, the most opposed,—*namely, the most* electro-negative (most acid), *oxygen*, and the most electro-positive (most basic), *potassium*, — form the two final members of the series; then the former is succeeded by those bodies which comport themselves like oxygen in their properties and combinations, while potassium is followed by those similar to itself. At the junction of the two series, the undecided elements are found, — those comporting themselves sometimes negatively and sometimes positively. If it is a law in chemistry, *that bodies combine together so much the more eagerly the more dissimilar they are to each other*, while bodies similar in their properties show at most only a very slight inclination to combine, then this scheme may present to us at the same time a probable idea of the affinities of the elements for each other. *Those bodies most remote from each other in the series have a great desire to combine, while those the nearest to each other have but little or no desire to unite.* Thus, oxygen *most* readily desires to unite with the potassium, next with the sodium, next with the calcium, barium, and so on; it comports itself most indifferently towards fluorine. Potassium, on the other hand, shows the greatest affinity for oxygen, then for the salt-formers, sulphur, &c.; but the least affinity for its neighbours and kindred, sodium, barium, &c. Let it be distinctly understood, however, *that this scale of affinity is a very fluctuating one*, and is subject in many cases to essential modifications.

−	+
Oxygen	Potassium
Fluorine	Sodium
Chlorine	Barium and Strontium
Bromine	Calcium and Magnesium
Iodine	Aluminium
Sulphur	Chromium
Selenium	Manganese
Phosphorus	Iron
Nitrogen	Zinc
Carbon	Nickel and Cobalt
Boron	Lead and Bismuth
Silicon	Copper
Arsenic	Mercury
Antimony	Silver
Tin	Platinum and Gold

Negative elements, or those forming preferably *acids.*

Undecided elements, forming sometimes *bases*, and sometimes *acids.*

Positive elements, or those forming preferably *bases.*

Hydrogen.

±

PART SECOND.

ORGANIC CHEMISTRY.

(VEGETABLE AND ANIMAL CHEMISTRY.)

ORGANIC CHEMISTRY.

VEGETABLE MATTER.

419. An inscrutable wisdom has given to the seed the power of germinating in the moist air, and of growing up into a plant, which puts forth leaves, flowers, and fruit, and then perishes and disappears. Germination, growth, flowering, seed-bearing, and decay are the principal stages of existence through which the plants have to pass. When they have produced seeds, that is, new bodies capable of life, they have fulfilled their destiny, and their course then tends downwards to decay. Whether they live only one short summer, or survive hundreds of years, the general principle remains essentially the same.

The Divine agency which effects these changes, and calls forth the phenomena of life in the vegetable world, is, in its essence, wholly unknown to us. A particular name, *vital power*, has indeed been given to it, but from this we derive no clearer conception or understanding of it. Its operations are conducted in such a mysterious manner, that it is not probable that the vague speculations of the inquiring mind on this point will ever lead to bright or clear ideas here below. We feel, indeed, the rushing of the vital current in the joy which penetrates us when in the spring this force causes the buds to expand, and covers the earth with showers of blossoms, as well as in the melancholy which seizes upon us when in the autumn the withering of the leaves announces to us its departure; but whence this force comes, and whither it goes, and how it calls forth, as it were by magic, the wonders of the vegetable world, we are indeed absolutely ignorant. That only which it produces, and from which it was produced, are comprehensible to our senses.

420. There are two ways open to the inquirer, by which he may gain a partial insight into the mysterious workshop of vegetable life: — 1st, that of *observation*, which, by the aid of the microscope especially, has led to a very accurate knowledge of the structure of plants, and of the *changes* which their separate parts (organs) undergo during their growth; 2d, that of *chemical experiment*, by which the constituents of plants, their food, and some of the *transformations of matter* occurring during the growth of the vegetables, have been discovered. The knowledge acquired in these two ways of the inward and outward changes which plants undergo during their existence, is called *vegetable physiology*.

421. There are generated in plants during their growth many substances having a perfect individuality of their own, which in many cases we can distinguish from each other by their taste. Grapes, carrots, and many other fruits and roots, have a sweet taste; they contain *sugar*. The branches and leaves of the grapevine have a sour taste; they contain an *acid salt*. Those of the wormwood have a bitter taste; they contain a pe-

culiar *bitter principle*. The latter emit also a strong odor, which proceeds from a *volatile oil*. In the seeds of the different species of grain, and in the tubers of the potato, we find a mealy substance, *starch;* in the seeds of the rape and of the flax-plant a viscous juice, *fat oil*. From the cherry and plum trees exudes a mucilaginous substance, which is soluble in water; from the firs and pines a similar substance, but which is insoluble in water; the former we call *gum*, the latter *pitch*. The magnificent colors of flowers proceed from a *coloring matter;* the noxious effects of poisonous plants from *vegetable bases*, &c. These substances are called by the general name of *proximate constituents of plants*. Many of them are to be found in almost *every* plant, while others occur only in *particular* species of plants.

We cannot *imitate* by art the workings of nature in living plants, as we were able to do most perfectly in inorganic chemistry. The chemist, by chemical analysis, has, indeed, determined with the utmost accuracy of what elements the proximate constituents of plants are composed, and in what proportions by weight; but he has never yet succeeded in reconstructing these constituents from their elements.

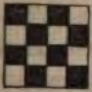
422. Unripe grapes taste sour, ripe ones sweet; therefore we conclude that during the ripening the acid of the grapes has been converted into sugar. Common barley tastes mealy; if suffered to germinate it acquires a sweet taste, because during germination a portion of its starch is converted into sugar. Similar changes occur in every living plant; indeed, they frequently take place when the vital power has become extinct in the plant. Potatoes, for instance, become sweet by allowing them to freeze; all the starch of the *germinated barley* is converted into sugar by adding

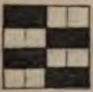
water to it, and letting it remain for some hours in a warm place. That which is thus produced by the vital activity of the plants, or by cold or heat, namely, *the transformation of one vegetable substance into another*, we are also able to effect by various other means. Art in this respect can indeed do more than nature, since it produces combinations — for instance, alcohol, pyroligneous acid, and many other compounds — which we never find ready made in the living plants. The number of these combinations may be increased almost innumerably by the aid of inorganic bodies, such as strong acids and bases, chlorine, &c.; — letting these operate upon vegetable substances, which are thereby changed in an infinitely varied manner, and transformed into new bodies. Thousands of such new combinations have been discovered within the last twenty years; our posterity will probably count them by millions.

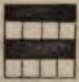
423. If you ask what are the elements of which the proximate constituents of plants are composed, the answer is, the four following are the principal ones, — *carbon*, *hydrogen*, *oxygen*, and *nitrogen*, — which are therefore called *organogens*. Many of the vegetable tissues contain all the four elements (C H O N), and are called *azotized* compounds; but others, and by far the largest proportion, contain only the first three elements (C H O), and are called *non-azotized* compounds. From these few elements, with the addition of small quantities of sulphur, phosphorus, and some inorganic salts, the Creative Power is able to produce the countless multitude of plants which cover the surface of our earth.

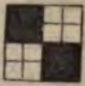
424. If it is obvious, from this simple constitution, that the great variety of vegetable matter does not depend upon the number of the constituent parts, we

must presume that this variety is owing to the different ways in which these four elements are joined together and combined with each other. And such is indeed the fact. It has already been mentioned (§ 274), that in the isomeric compounds, that is, in such as possess the same composition, but not the same properties, a different arrangement of the atoms is to be supposed; in the same manner as in a chess-board, where the white and black squares may be grouped together, either 2 and 2, or 3 and 3, or 4 and 4, &c. This variety in the grouping of the atoms, which happens only as an exception among inorganic substances, occurs as a general rule among organic compounds; and it has here so much the larger scope, because always three or four, and sometimes even more elements, are present, which enter into combination with each other, while, in the department of inorganic chemistry, commonly only two elements unite with each other; and likewise because it is a law in organic chemistry, *that the atoms of the elements do not unite singly, as with minerals, but always in groups; namely*, 2, 3, 4, 6, 8, 10, *or more atoms of one element, with any number of atoms of the other elements.*



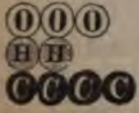






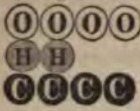
Organic substances have, therefore, an incomparably *more complicated constitution* than the inorganic compounds, as the following examples show.

Fig. 165.



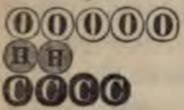
From the well-known amber, a peculiar acid, *succinic* acid, is obtained, which consists of four atoms of carbon, two atoms of hydrogen, and three atoms of *oxygen*, and has accordingly the formula $C_4 H_2 O_3$ (see Fig. 165).

Fig. 166.



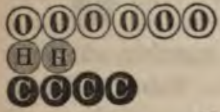
If one atom of oxygen is added to this, we have the constitution of *malic acid* = $C_4 H_2 O_4$ (see Fig 166).

Fig. 167.



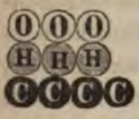
If one more atom of oxygen is added, that of *tartaric acid* = $C_4 H_2 O_5$ (see Fig. 167).

Fig. 168.



And by adding yet another atom of oxygen, that of *formic acid* = $C_4 H_2 O_6$ (see Fig. 168).

Fig. 169.



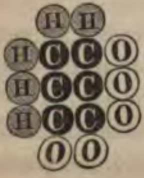
But, on the other hand, if one atom of hydrogen is added to the succinic acid, which was the starting-point, the constitution of *acetic acid* is obtained = $C_4 H_3 O^3$, &c. (see Fig. 169).

If we are not yet able to produce all the transformations as they are here given, yet the possibility of succeeding at some future time cannot be doubted.

Sugar, starch, and wood have precisely the same constitution, namely, $C_6 H_5 O_5$; they are *isomeric*. If we imagine these three elements grouped together in different ways, as, for instance,

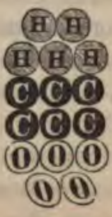
in sugar:

Fig. 170.



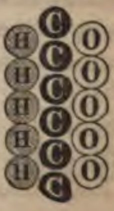
in starch:

Fig. 171.



in wood:

Fig. 172.



then we can form an idea how one and the same quantity of the same elements may combine, forming such very different bodies; and it would not now excite any great astonishment, if, on further investigation, hundreds of different substances of the same constitution should be discovered, since, by mere transposition of the above sixteen atoms, more than a hundred different arrangements or groupings may be produced.

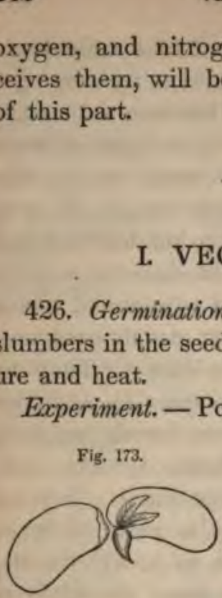
425. The *instability* of organized substances, which has already been referred to, is now simply explained by these complex proportions of the atoms. They are like complicated machinery. In the spinning-wheel we have one wheel, one spindle, and one band; but in a spinning-machine, hundreds of wheels, spindles, and bands, all connected together into one whole. Now, as in complicated machinery a wheel is more likely to come off, a spindle to bend, a wire to break, thereby causing a greater disturbance throughout the whole of the machine than can possibly happen in the simple spinning-wheel, so also complex organic bodies are much more liable to disorganizations and changes than the more simple inorganic bodies. For if in the former only one of the many atoms leaves, or even changes, its place, or if another atom, whether of the same or of a different element, is added to it, the body at once ceases to be that which it was, and becomes a new peculiar compound. The familiar terms combustion, ignition, singeing, charring, rotting, decaying, fermenting, curdling, growing musty and sour, bleaching, fading, &c., are all *chemical metamorphoses* of the kind referred to, and it is well known that these metamorphoses are peculiar to animal and vegetable substances.

The sources from which the vegetable world derives its four fundamental substances (carbon, hydrogen, oxygen, and nitrogen), and the form in which it receives them, will be treated of more fully at the close of this part.

I. VEGETABLE TISSUE.

426. *Germination of the Seeds.* — The vital force slumbers in the seed; it is called into activity by moisture and heat.

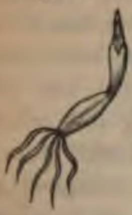
Fig. 173.



Experiment. — Pour water over some beans, and let them remain in a moderately warm place, till the embryos burst forth, and the swollen seeds divide into two parts. If we now examine them closely, we shall perceive at the extremity of each seed, where the germ appears, two delicate white leaflets; from these, as the plant continues to grow, the stem and leaves are developed, while the other extremity of the germ forms into a root. The solid mass of which these young organs consist is called *vegetable tissue;* it consists of variously-formed cavities, which are filled with a colorless liquid, the *sap.* If the bean-plant is exposed to the action of light, a green coloring matter (*chlorophyll*) is produced in the sap; but this substance is not formed in the roots, since they are screened from the light by the surface of the earth. The two lobes of the bean (*cotyledons*) gradually disappear as the development of the plant advances; they serve as its first nourishment. The embryo of most plants is furnished with a pair of cotyledons (*dicotyledonous*).

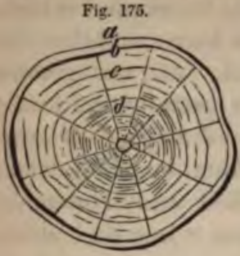
Experiment. — Barley, when caused to germinate in the same manner, puts forth only a single embryo, from which first the leaves and then the stalk are developed. All our grasses and bulbous plants germinate in this manner (*monocotyledonous*). If you pour off the water from the barley when the seeds are swelled and thoroughly steeped, and then put it in a cool place, piled up in heaps, you can, by occasionally turning it, so retard and regulate the growth that the radicles only will sprout forth. If you now arrest further vegetation by quickly drying the grain in a warm oven, the brewers' *malt* is obtained. The rootlets may be easily rubbed off after drying; they yield an excellent manure, and consist principally of vegetable tissue rich in potassa and other salts, which salts, during the process of germination, have passed from the grain into the radicle.

Fig. 174.



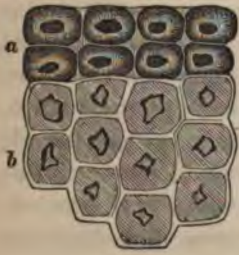
427. *Vegetable Tissue.* — All the cells and vessels of plants are composed of vegetable tissue. This substance is to plants what bones, flesh, and skin are to the animal body; it forms the solid mass of all vegetable organs, and consequently imparts to plants their shape and firmness; it forms the ducts or veins of the plants, through which the sap circulates. We find it very finely ramified, tender, soft, and easily digestible in the young leaves, flowers, and stems, and in the so-called pulp of fruit and roots, as apples, plums, carrots, &c.; hard and indigestible in straw, wood (*woody tissue*), and in the husks of grain (*bran*); hardened like stone in the stones of plumbs, cherries, and peaches, and in the shells of nuts; light, porous, and elastic in the pith of the elder, and in cork; lengthened and pliant in hemp, flax, and cotton.

Fig. 175.



428. The transverse section of the stem of a tree illustrates the influence which age exerts upon the vegetable tissue, and how this tissue varies in one and the same tree. Inside the *bark* (*a*) lies the *inner fibrous bark* (*b*), which consists of lengthened tubes, and is peculiarly adapted to supply the place of veins in the tree. Here the sap principally circulates, and therefore a tree will die when the inner bark is girdled, whilst (as seen in many hollow trees) the tree will live on if only the inner and outer bark remain, though the wood itself is entirely rotten and gone. From the inner bark towards the exterior is deposited every year a new layer of bark, and towards the centre a new layer of wood (annual circles). The light and whiter wood, lying next the inner bark, is called the *sap-wood* (*c*); but this, by the annually increasing compressure, becomes denser and more solid, and then it is called *heart-wood* (*d*). The latter is usually darker, and is frequently impregnated with coloring matter (red-wood). The annexed figure will give an idea of the artistical internal structure, which is manifest even in apparently simple dense wood, as viewed under a strong magnifying-glass. It represents the transverse section of a pine bough, the portion marked *a* representing young ligneous cells, those marked b the matured cells.

Fig. 176.



Most plants contain in the inner and outer bark a styptic-tasting substance, soluble in water, and which is known by the name of *tannin*, or *tannic acid*.

429. *Linen* is the inner bark of the flax-plant. During the process of *retting*, the outer bark, by the long-continued influence of moisture and air, passes over into decay, and then, after rapid drying, may be rubbed off by bending it backwards and forwards (*breaking*); but the filaments of the inner bark, which do not so readily decay, remain behind, and after being parted into their finest fibrils, and arranged parallel by the so-called *heckling*, form the well-known *flax*. The tow, which falls off during this process, consists of tangled fibres of the inner bark.

Flax has a gray color, because it contains a gray coloring matter, which is not soluble in water and lye, though it becomes soluble in lye by exposing the flax, the thread spun, or the linen woven from it, during a long time, to the action of light, water, and air. This is done in the bleaching-yard by spreading it on the grass (*grass bleaching*). The coloring matter, hereby altered and rendered soluble, is removed from time to time by boiling with lye. Bleaching may be accomplished more rapidly by the application of chlorine, which, on account of its very strong affinity for hydrogen, attracts hydrogen from all organic substances, whereby they become colorless and soluble (*chlorine bleaching*). The question here oocurs, Why is it that in these two bleaching processes the coloring matter alone, and not the vegetable tissue at the same time, is decomposed? The reason is, because the coloring matter consists of four elements (C H O N), but the vegetable tissue of only three elements (C H O); according to § 425, the more complicated substance, consisting of four elements, is more readily and rapidly decomposed than the less complicated substance, consisting of three elements. If, when the linen has become white, the bleaching were still continued by either of these methods, the vegetable tissue would then be decomposed and become rotten; a case which often occurs when linen, cotton, or paper is treated too long, or with too strong a solution of chlorine.

430. *Bast.* — Soak the bark of the linden-tree in water till the outer bark is decomposed, and has become brittle; when it is dry the inner fibrous part of the bark can be peeled from it, and it then forms the *linden bast*, used for tying up plants. The outer covering of the trees, which is commonly, but erroneously, called bark, consists by no means of the proper bark alone, but of two essentially different parts, which have grown very closely together; the external layer is the proper bark (*epidermis*), the inner is the bast (*liber*).

431. *Cotton* consists of delicate hollow hairs, which form in the cotton-plant in considerable quantities around the seeds. As it exists in nature it is beautifully white (except the Nankin cotton, which is yellow), and consequently requires no bleaching. When, however, cotton thread or cotton fabrics are bleached, it is merely in order to remove the oily, sweaty, and mealy substances (*weaver's glue*, &c.) which have become attached to them during spinning and weaving. This is now usually effected by boiling with soda-lye or milk of lime, or immersing them in a weak solution of chloride of lime. The lime which remains adhering is then removed by exceedingly diluted acids (*acid bath*), and the acid, in its turn, by rinsing in water.

It is well known how important the above-mentioned sorts of pliant vegetable tissue are, on account of their application for making thread, twine, and fabrics of every variety; we clothe ourselves in woody fibre, we write and print upon it, we build our houses of it, &c.

432. *Vegetable Tissue and Water.* — *Experiment.* — Pour some lukewarm water over sawdust, and let it stand for a day; then squeeze out the liquid through a cloth and boil it; a slight turbidness will appear, and on longer standing a loose sediment will be deposited. Water does *not* dissolve the woody fibre, though it does the sap contained in it; in this sap, as in that of all other plants, there is always found a substance in solution, which is very analogous to the white of eggs, and which, like it, coagulates in boiling; it is called *vegetable albumen.* There are also contained in the liquid, separated from the albumen, various other substances in solution (mucus, gum, tannin, &c.), which are not precipitated by boiling. If the sawdust, after it has been dried, is treated with alcohol, this will also dissolve some substances (pitch, &c.); and so also will ether, lye, and other liquids. Therefore, in the preparation of perfectly pure woody tissue, it must be treated with various solvents in order to remove all the constituents of the sap.

CHANGES OF VEGETABLE TISSUE.

a.) Changes of Vegetable Tissue by Acids.

433. Wood, when dipped in *sulphuric acid,* is charred; when in *nitric acid,* it is dyed yellow, and by longer immersion it is entirely decomposed, as has already been observed (§§ 160, 173). Sulphuric acid attracts from the woody fibre hydrogen and oxygen, which combine to form water, and then unite with the sulphuric acid; nitric acid *yields oxygen to it,* and consequently oxidizes

it. By very long continued treatment, all the carbon of the wood may finally be oxidized into carbonic acid, and all the hydrogen into water. Chlorine decomposes the vegetable tissue by abstracting hydrogen (§ 429). Diluted sulphuric acid operates very differently from the concentrated acid; if paper, linen, &c., are boiled for several hours with the former, the vegetable tissue is converted, first into gum, and finally into sugar.

Explosive Vegetable Tissue, or *Gun-Cotton* (*Pyroxylin*). — By exposing vegetable tissue (cotton, hemp, linen, sawdust, &c.) for a short time to the action of highly concentrated nitric acid, it acquires the remarkable property, like that of gunpowder, of igniting and exploding with great violence when touched by a lighted match.

Experiment. — Mix half an ounce of the strongest nitric acid (sp. gr. = 1.5) with one ounce of strong sulphuric acid; pour the mixture into a porcelain mortar, or a cup, and press into it with the pestle as much cotton (wick-yarn, cotton-cloth, printing-paper, &c.) as can be moistened by the acid. When the cotton has soaked for five minutes, it is to be taken out with a glass rod, put into a vessel containing water, and washed repeatedly with fresh quantities of water, until it no longer reddens blue test-paper. The cotton is then squeezed out with the hand, spread upon a sheet of paper, and dried in an airy place. It is dangerous to dry it upon a stove, as it easily takes fire.

If the *gun-cotton* thus prepared is struck smartly with a hammer upon an iron anvil, it detonates violently; when touched with a hot wire or a lighted match, it burns instantaneously, without leaving any residue; when fire-arms are loaded with it, it acts like gunpowder, but its explosive power is three or four times greater than that of the latter. Gun-cotton being, therefore, an exceedingly dangerous substance, the *greatest caution* is indispensable in conducting experiments with it, and only very small quantities should be used at once.

The chemical changes which cotton undergoes by immersing it in the above acid mixture consist chiefly in this, that it gives up a portion of its hydrogen and oxygen (as water), and receives instead nitric acid (consequently, nitrogen with much oxygen). Gun-cotton contains, therefore, *much more oxygen* than the common cotton, and likewise *nitrogen*, in chemical combination; the former causes the rapid combustion, while the latter, together with the gases formed by the combustion, causes the rapid explosion. The sulphuric acid coöperates only indirectly, by attracting and retaining the water contained in the nitric acid, and that which separates from the cotton.

b.) Changes of the Vegetable Tissue by Alkalies.

434. The effect of alkalies on vegetable tissues may readily be seen by wrapping a piece of quicklime in paper, and letting it remain there for some weeks, when the paper will become quite rotten. The farmer and the gardener, being well acquainted with this action, are accustomed to mix in lime or ashes with couch-grass and other weeds, to accelerate the rotting and decay.

c.) Changes of the Vegetable Tissue by Heat, with free Access of Air.

435. That wood, &c., when heated with access of air, is consumed, that is, is decomposed into carbon and water, has already been fully treated of in the former

part of this work. *All vegetable substances are consumed in the same way, by means of the oxygen of the air.* If inorganic substances (salts and earths) are present, they, since they are not volatile, remain behind as *ashes.*

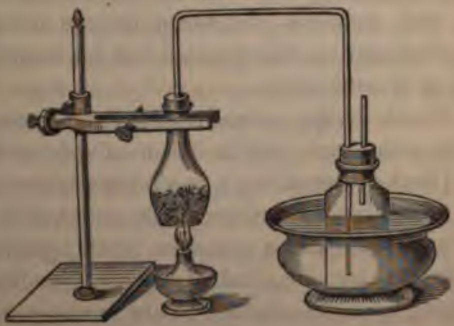
Vegetable, and likewise animal substances, can be consumed, not only by the oxygen of the air, but also by the oxygen of other bodies; as, for example, by that of oxide of copper, of chromate and chlorate of potassa, or directly by pure oxygen itself. If the water formed during the combustion is absorbed by chloride of calcium, and the carbonic acid by a solution of potassa, then, by the increased weight of the chloride of calcium and the potassa, the quantity of the water and of the carbonic acid may be ascertained, and from these the weight of the hydrogen and carbon which the consumed body contained may be calculated. That which is wanting in the weight of the original body under examination is the amount of oxygen which it contained. In this manner the three elements comprised in an organic body, carbon, hydrogen, and oxygen, may be very accurately determined; such an examination is therefore called an *elementary analysis.* If, in addition to the three above-named elements, an organic body contains nitrogen also, it escapes uncombined during the combustion in the form of gas, and can be collected and estimated by a special method of analysis. But on heating such bodies with bases having a strong affinity for water, — for instance, with hydrate of potassa or soda and lime, — then (with but few exceptions) the nitrogen contained in them escapes in combination with hydrogen, as ammonia, from which the contents of nitrogen can be accurately calculated.

d.) *Changes of the Vegetable Tissue by Heat, the Access of Air being prevented.*

436. *Imperfect Combustion of Wood.* — When wood is heated with insufficient access of air, as is the case, for instance, in most of our stoves, a portion of the carbon remains unburnt, and is deposited as *soot* from the gases which form the flame. Moreover, during the process, a portion of the burning carbon takes up only half as much oxygen as when there is an abundant supply of air, and there is formed, not only carbonic acid, but also carbonic oxide gas (fumes of charcoal). But, besides these compounds, other singular substances are formed, as is indicated by the peculiar smell of the smoke, and by the lustrous acid and resinous soot deposited upon the lower parts of chimneys. The products of the decomposition of vegetable tissue may be more clearly recognized if you heat the wood with entire exclusion of air.

Experiment. — Subject wood, as was described in § 119, to dry distillation; you obtain a great variety of products easily to be distinguished by characteristic

Fig. 177.



properties; — 1. *charcoal*, which, since it is not volatile, remains behind; 2. *illuminating gas*, a mixture of carburetted hydrogen, carbonic acid, and carbonic oxide gases; 3. *wood-vinegar*, a watery acid liquid; 4. *wood-tar*, a thick, brown, resinous liquid. The two former substances have been already described, so that only the two latter remain to be more fully considered.

437. *Pyroligneous Acid, or Wood-Vinegar.* — One pound of dry beech-wood yields nearly half a pound of pyroligneous acid. In its crude state it has a brownish-black color, owing to the tar which it contains in solution, and a smoky odor, together with a very acid, disagreeable, smoky flavor. On account of its containing acetic acid, and its cheapness, it is now much used in the preparation of acetates, particularly such as are employed in calico-printing and dyeing; for instance, acetate of iron, of lead, of soda, &c.

Experiment. — Pour some wood-vinegar upon a piece of lean meat, and let it soak for a few hours; it can then be dried and packed without passing into putrefaction, as in a few hours it has experienced the same change, and acquires the same degree of firmness, usually produced by being suspended for months in the smoke (*rapid smoking*).

438. Wood-vinegar owes its antiseptic properties to a peculiar substance, which has received the name of *creosote* (flesh-preservative); one pound of pyroligneous acid contains about a quarter of an ounce of it in solution. Pure creosote is a colorless liquid, gradually becoming brown by age, and of an oily consistency; it has a strong smell of smoke, a very burning taste, and disorganizes the tender skin of the tongue or the mouth, and, taken internally, is a powerful poison. Creosote is now frequently applied as a remedy for the toothache,

when it is usually mixed with oil of cloves; but it must also be diluted with alcohol, in which it readily dissolves, as its action would otherwise be too corrosive. One dram of water will dissolve one drop of creosote; this solution (*creosote-water*, or *aqua Binelli*), which acts upon flesh in the same manner as the pyroligneous acid, is employed as a sedative. The smoke which is formed in our stoves by the incomplete combustion of wood, or of pit-coal, always contains fumes of creosote, to which is owing its peculiar smell, and its property of causing lachrymation. Every thing which prevents complete combustion, such as a deficient draught of air, or moist fuel, must, accordingly, favor the formation of creosote, and render the smoke more irritating. Flesh is most effectually cured by this smoke, which is expressly generated for this purpose by burning green fagots, or obstructing the draught of air.

439. When pyroligneous acid is very slowly distilled, a spirituous, volatile liquid, very similar to brandy, first passes over, which is called crude *pyroxilic spirit.* The chief component of this fluid is a substance which, in its properties and changes, has great similarity to alcohol, or spirits of wine, though its constitution is different. On account of this similarity, it is called pyroxilic spirit (*hydrated oxide of methyle*).

440. *Wood-tar* is of a resinous nature, that is, insoluble in water, though soluble in alcohol; it is moreover very rich in carbon, as is in some degree indicated by its black color. On distillation, it separates into a volatile oil (*oil of tar*), and into a non-volatile black pitch (§ 576). This separation takes place, also, but more slowly, when wood is smeared with tar; the pitch, hardening in the pores of the wood, then prevents the penetration of the water, and hereby, as by

the creosote also contained in the tar, the decomposition of the wood by putrefaction is arrested (tarring and calking of ships, &c.).

The dry distillation of wood shows in a very striking manner with what extraordinary readiness organic substances may be decomposed and transformed into very remarkable new bodies. The wood has only to be heated in order to be resolved into an acid and a spirituous body, — into oily and resinous substances, — into illuminating gas and carbon. And these are not all the products of the decomposition of wood. Besides the substances here mentioned, a dozen others, at least, have been discovered, which are generated simultaneously with them, and each of which may be converted by heating, by treating with acids, bases, chlorine, &c., into numerous other bodies. Here a great field opens for chemical investigation, a field which has indeed no bounds, and which must be so much the more extended, since *all vegetable matter, heated with exclusion of air, becomes charred and decomposed into products of combustion, but which are different in different bodies*, as is obvious in the dry distillation of tobacco in tobacco-pipes, of pit-coal, brown coal, &c.

441. *Imperfect Combustion of Pit-Coal.* — Pit-coal and brown coal are formed from the vegetables of a former era, which were washed together in heaps during some revolution of the earth, and deeply buried beneath mud and soil. When pit-coal is heated with exclusion of air, we obtain, in the same manner as from wood, — 1. carbon (coke); 2. a combustible gas (illuminating gas); 3. an aqueous, empyreumatic liquid (tar-water); and 4. a resinous, black, viscid liquid (pit-coal tar).

The aqueous empyreumatic liquid obtained from pit-coal contains only a trace of vinegar, but in larger quantities a basic body, ammonia, combined with carbonic acid; it may therefore be employed as a manure, or for the preparation of sal ammoniac.

The *pit-coal tar*, which is now very generally employed for smearing over wood, iron, and the roofs of buildings, to protect them from moisture, may also, like wood-tar, be separated by distillation into a volatile substance (oil of coal-tar), and into a pitchy, non-volatile substance (artificial asphaltum); but the peculiar substances (kyanole, pyrrol, leucol, carbolic acid, rosolic acid, brunolic acid, naphtaline, &c.) contained in the latter are quite different from those of the former. Of these substances, *naphtaline*, a white, camphor-like body, has been examined most closely; but the names only of some of the new combinations resulting from these researches will here be mentioned, to show, alas! with what a flood of new and strange names this single substance has inundated chemistry. The following compounds are formed by the action of nitric acid upon naphtaline: nitronapht-alase, -aleise, -alise, -ale, -esic acid, -isic acid, phtalic acid, phtalamide, &c.; by treating with chlorine: chloronaphta-lase, -lese, -lise, -lose, &c.

442. A decomposition similar to that which pit-coal undergoes during dry distillation must also be produced, perhaps, in many places in the interior of the earth, by volcanic heat, for we know that in many countries substances either issue from the earth, or are imbedded in it, which have a very great similarity to the products of the distillation of pit-coal, as is shown in the following arrangement.

Artificially produced from Pit-Coal.	Occurring Native in the Earth.
a.) *Illuminating gas.*	a.) *Inflammable gases* (sacred fire of the Bramins), issuing here and there from the crevices of rocks.
b.) *Oil of coal-tar.*	b.) *Naphtha*, oozing out of the earth in Persia.
c.) *Oil of coal-tar.*	c.) *Mineral tar*, found in many places in Persia and France.
d.) *Artificial asphaltum* (pitch of pit-coal).	d.) *Natural asphaltum* (pitch of Judea), found in the Dead Sea, and other Asiatic seas.
e.) *Ammoniacal empyreumatic liquid.*	e.) *Ammonia*, issuing in a watery vapor, associated with boracic acid, from the earth near Tuscany.
f.) *Coke* (C).	f.) *Anthracite* (C), like pit-coal, occurring in immense beds in the earth.

e.) *Changes of the Vegetable Tissue by Air and Water.* (*Decay and Putrefaction.*)

443. *Decay.* — When vegetable tissue — for instance, wood, leaves, straw, &c. — is exposed to the influence of the air, it imbibes moisture, and becomes gradually brown and rotten, — it passes into *decay.* The chemical process which thus takes place very much resembles those changes which wood undergoes in combustion, except that it takes place far more slowly; what is effected by combustion in minutes is effected by decay only in the course of years. By combustion, the constituents of the wood and the oxygen of the air are converted into carbonic acid and water; the same products are also formed on the decay of wood. In combustion, the hydrogen is oxidized more rapidly than the carbon; the same happens also in decay. This explains why wood, on combustion, as well as on decay, assumes a darker — first a brown, and then a black — color. When proportionably more hydrogen passes off than carbon, the residue must necessarily, as the decomposition continually progresses, be richer in car-

bon, and consequently, as a general rule, also of a darker color.

444. *Humus.* — The brown or black substance into which vegetable matter is converted by decay has received the name *humus.* As wood, which is only partially consumed, can be consumed still further, so also humus is gradually further decomposed, and in most cases, after complete combustion or decay, there is finally left only a small quantity of non-volatile salts and earths, — *the ashes,* — which the wood has absorbed from the earth during its growth. If these two processes of decay are supposed to be going on in two distinct periods, then there are formed, —

in combustion,		*in decay,*	
from the *wood* in the 1st period,	water (much), carbonic acid, half-burnt wood;	from the *wood* in the 1st period,	water (much), carbonic acid, humus;
from the *half-burnt wood* in the 2d period,	water (little), carbonic acid;	from the humus in the 2d period,	water (little), carbonic acid;
there remain,	ashes.	there remain,	ashes.

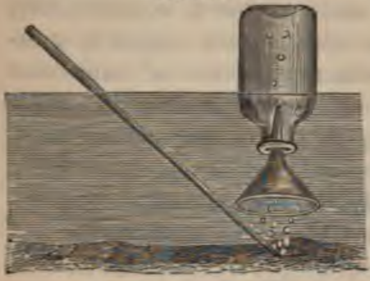
Humus is identical with decaying Organic Matter. — In this acceptation it has for many years been known and valued in agriculture. Vegetable mould (humus) is the term applied to the upper black or brown layer of earth, which has been formed in forests by the decay of the leaves which fall off; the dark, fat, arable soil, containing much partially decomposed organic matter, is said to be rich in humus, while the dry, light soil, in which it is wanting, is said to be poor in humus. The farmer knows that, contrary to what happens in his woodlands, the humus diminishes in his fields, and so much the more rapidly as the crops are more abundant; he knows that fields rich in humus are, as a general rule, more fertile than those which are poor in humus. Therefore he seeks to restore to his land the humus consumed in vegetation by ploughing in straw and animal excrements (*manuring*), or fresh plants (*green manuring*), or by the alternation of plants which leave behind many roots in the soil (*fallow plants*) with such as are only feebly rooted (*grain*). On an acre of land which was cultivated with clover, several thousand pounds of roots remained behind in the soil; upon one cultivated with wheat or grain, only from one fifth to one sixth as much; it is therefore apparent, that in the former case from five to six times more humus must be generated by the decay of the roots than in the latter. The increase of fertility which the farmer thus aims at is, however, *by no means* to be ascribed to the humus alone, since the inorganic constituents (salts and earths) which are present in manure and in the soil have a *principal* share in it (§ 611).

If we consider the formation of *humus*, we shall at once perceive that various substances are included under this term; for its constitution alters every day, since a little of its carbon and hydrogen is every day oxidized and separated. We may easily conceive, that very old humus may contain as much again carbon as that which is recent, or even more. The ideas concerning humus became still more vague when chemists first thought of designating by this name other brown and black colored substances, the products of the evaporation of vegetable juices or decoctions, or which were formed from wood, starch, sugar, &c., by boiling the latter with acids or alkalies. The term *humus* thus became, as it were, a foundling-hospital, into which were brought all the substances formed from vegetable or animal matter, provided they were black or brown, and were insoluble, or nearly insoluble, in water. The humus generated by decay, as we find it in arable soil, is now thought to be a mixture of several distinct brown substances, namely, of ulmine, humine, ulmic acid, humic acid, geic acid, crenic and apocrenic acids, which are produced consecutively, according to the above series, from vegetable matter. The two latter acids are soluble in water, and are partly the cause of the yellow or brownish color which we perceive in the water of marshes or bogs; the other three acids are only soluble in water when alkalies are added; finally, the first two substances, ulmine and humine, can neither be made soluble by water nor by alkalies. Accordingly, by the general term *humus* we must understand a mass of brown decaying matter, partly soluble, partly insoluble, partly acid, partly neutral, which, with the uninterrupted presence of air, water, and heat, may be still further decomposed, and thereby *carbonic acid* and *water* evolved. Carbonic acid and water are indispensable to the nourishment of plants; hence, in a soil rich in humus, the plants will grow more vigorously, because they find there, and can absorb by their rootlets, more of these two nutritive substances than they could in a soil poor in humus. Humus exerts, moreover, a beneficial influence upon vegetation, because it loosens the soil by the development of carbonic acid, because it possesses the power of attracting water from the air, and of retaining it for a long time, and because, by means of the acids contained in it, it is able to abstract from the air, and also from manure, the third means of nutriment for plants, ammonia.

445. *Putrefaction.* — The decomposition of vegetable tissue takes place in a somewhat different manner

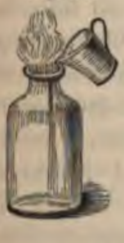
when the air is entirely or partially excluded, — for instance, when the decomposition takes place *under water*, as we observe in ponds, marshes, and rivers.

Fig. 178.



Experiment. — Thrust a pole into the mud of a pond, and catch the bubbles which rise, in a bottle filled with water, and held inverted over them; when all the water is displaced from the bottle, close it up while under the water. Introduce a little water into the bottle, and afterwards a small piece of caustic potassa or quicklime, close it immediately, shake it a few minutes, and then remove the stopper under the water; a part of the water will press into the bottle, because the bases have absorbed a portion of the gas. The gas absorbed was *carbonic acid.* If you now apply a burning match to the mouth of the bottle, and expel the remainder of the gas by pouring in water, it will ignite and burn with a blue flame. This is called *marsh gas* (light carburetted hydrogen gas); it consists of carbon and hydrogen, like the common illuminating gas, but it contains, compared with this, a smaller quantity of carbon, and therefore burns without giving a bright light. These two gases, carbonic acid and marsh gas, originated in the wood, leaves, branches, roots, &c., of the vegetables which sunk to the bottom of the water, and were there decomposed.

Fig. 179.



When oxygen is wanting, the hydrogen of the vegetable tissue combines with a portion of the carbon, while, if there is an abundant supply of oxygen, the hydrogen unites with the latter. Here, too, a substance similar to humus, and richer in carbon, remains behind; in ponds, as a black *mud*, in marshes, as *peat*. This kind of decomposition is called *putrefaction;* it is somewhat analogous to the change which wood undergoes on incomplete combustion (*charring*, *dry distillation*), as is shown by the following arrangement: —

In charring,		*In putrefaction,*	
the vegetable tissue is converted into	*a.*) illuminating gas,	the vegetable tissue is converted into	*a.*) marsh gas,
	b.) carbonic acid,		*b.*) carbonic acid,
	c.) partially consumed substances (tar, coke, &c.).		*c.*) partially rotted substances (mud, peat).

446. Peat is formed from marsh plants, which slowly rot under water; every year a new vegetation arises, which, on perishing, sinks to the bottom, and thus, in the course of time, a morass is formed. The young peat consists of a brown, fibrous network, in which the separate parts of the plant may be clearly distinguished; but after a time it decomposes into a black, slimy mass, which may be cut into pieces of the shape of bricks. The old, black turf only smoulders away on burning, a proof that the hydrogen of the plants from which it was formed has mostly disappeared during putrefaction.

447. As above stated, carbonic acid was continually generated in the formation of peat; a portion of this carbonic acid remains in solution in the water, and this explains why the water which percolates through

beds of peat into the earth, and reappears as springs in deeper places, often contains so much carbonic acid that it can be used as *mineral water* (acidulous springs). If the water during its course meets with rocks containing protoxide of iron, lime, magnesia, &c., it may, by means of its carbonic acid, dissolve small quantities of them (§§ 237, 276). In this manner many of the mineral waters occurring in nature originate, as, for instance, the celebrated Marienbader springs, &c.

448. Besides peat, we find two other vegetable substances in the earth, which are likewise used as fuel, on account of their richness in carbon, — *brown coal* and *pit-coal.* Both are the remains of a vegetation which covered the earth before it was inhabited by man. It is highly probable that they were formed from the vegetables and trees of a primeval age, when, by inundation, or some other violent revolution which the crust of the earth underwent, they were buried under immense beds of sand and clay, and were there decomposed by a process similar to that of putrefaction, while the sand hardened into sandstone, and the clay into slaty clay or shale. In those places where the layers of earth were not sufficiently strong to prevent the escape of the carbonic acid and of the marsh gas, we often find, as, for instance, in many species of brown coal, the form of the wood so well preserved, that the annual rings may be distinguished in it (bituminous wood); but in other places the wood is transformed into a brown mass, which has a strong resemblance to humus, or peat (brown coal). But if the pressure of the superincumbent mass of earth was so strong as to prevent the escape of the gases formed during the decomposition of the imprisoned plants, they must necessarily have re-

mained behind with the coal. This, together with the compressure of the weight of a layer of earth or stone a thousand, perhaps several thousand, feet thick, accounts for the dense, compact, stone-like nature of many kinds of coal, especially of pit-coal, and also for their property of burning with a flame. Those gases which were condensed in the coal we obtain again, as illuminating gas and carbonic acid, when we heat the coal in a retort.

It is generally known that moist vegetable matter, as grass, hay, manure, &c., becomes hot, and is converted into a black, carbonaceous rich mass, when piled together in compact heaps. This *smouldering sort of carbonization*, taking place here on a small scale, must occur also on a large scale, when, by some revolution of the earth, masses of plants are washed together in heaps, and covered over with mud; and this smouldering must be so much the more complete the greater is the pressure under which the decomposition takes place, and the longer the time occupied in effecting it. Pit-coal is usually found at greater depths in the earth, and between older layers of rocks (in the transition rocks), than the brown coal, which mostly occurs nearer the surface of the earth, between more recent layers of rocks (in the tertiary rocks); we therefore conclude that the formation of pit-coal commenced at an earlier period, and that of brown coal not till a later period. The extraordinary differences occurring in this process of decomposition, according to the *variety* of plants, and the coöperation of more or less water, heat, air, pressure, &c., are very evident in the extraordinary *variety* of the products formed. Many of the pit and brown coals burn with a vivid flame, others with a feeble one, and some without any; many melt in the heat, others crumble to a sandy powder; many yield but one per cent. of ashes, while others yield from 25 to 30 per cent., &c.

449. *White Rotten Wood.* — *Experiment.* — Put, during the summer, some sawdust, moistened with water, in a closed vessel, and let it stand for some months; the wood will gradually lose its firmness, and be converted into a *white, friable substance.* A splinter of wood will not continue to burn in the air of the vessel, since the air no longer contains free oxygen, but carbonic acid. The water, too, has disappeared: it has chemically combined with the woody tissue. A similar transformation frequently occurs in the interior of the trunks of trees, where the air cannot have free access; the well-known white rotten wood is formed in this way. When the air has free access, a brown substance (humus, ulmine) is produced, such as occurs in hollow elms, willows, lindens, and other trees.

The decomposition to which wood is exposed by decay and putrefaction may be *retarded* and *checked*, —

1. By rapid drying, whereby the water of the sap is removed.

2. By steeping in water or steam, by which process the sap is dissolved and removed.

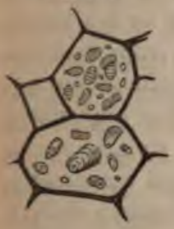
3. By smearing with bodies which prevent the penetration of the water; for instance, with varnish, tar, pitch, &c.

4. By impregnating with saline solutions, which act antiseptically; for instance, with corrosive sublimate (kyanizing), salts of lime, iron, &c.

II. STARCH, OR FECULA.

450. A MEALY substance, which is known under the name of *starch*, or *fecula*, is deposited in most vegetables, particularly at the period of ripening, from the juices with which the cells of the plants are filled.

Fig. 180.



It appears to the naked eye like particles of meal, but under a powerful microscope it is found to consist of small, generally regular grains or globules. Their position in the plant is shown in the annexed figure, which represents a section of some of the cells of a potato.

If a fresh plant is bruised and macerated in water, and the liquid then squeezed out, a large portion of the starch will pass with the juice from the vegetable tissue, and will settle, after standing quietly awhile, as a mealy mass. Potatoes, grain, and leguminous plants are very rich in starch.

451. *Potatoes.* — *Experiment.* — Rasp some potatoes on a grater, knead the pulp thus obtained with water, and squeeze it in a linen cloth; the *fibrous particles* of the cells remain behind, but the juice, together with a large portion of the starch, runs through. If you let the turbid liquid remain quiet for some hours, it becomes clear, because the heavier *starch* settles at the bottom. Now decant the liquid, wash the starch several times with fresh water, allowing it to settle each time, and then dry it in a moderately warm place.

Experiment. — Heat in a flask the clear liquid decanted from the starch; it becomes turbid when the heat approaches the boiling point, and, after boiling for a few moments, deposits a flaky, grayish-white substance, which is to be collected on a filter. It is the same substance already referred to (§ 432), *vegetable albumen*, characterized by its property of dissolving in cold and warm water, but of coagulating in boiling water. It contains nitrogen, which the starch does not.

Experiment. — Put some of the coagulated albumen upon a piece of platinum foil, and heat it over a lamp; it will burn and emit a very disagreeable empyreumatic odor. When starch is treated in the same manner, it also gives off an empyreumatic, but far less unpleasant smell. All azotized substances comport themselves in this respect like albumen; all non-azotized substances, like starch; therefore, when a piece of woollen cloth is singed, it diffuses a far more disagreeable odor than a piece of cotton or linen, because nitrogen is contained in the wool, but not in the cotton or linen.

A freshly-cut potato has a white color, which, however, on longer exposure to the air, passes over to brown; a similar change takes place in the liquid pressed out from the grated potatoes; at first it is colorless, but gradually becomes darker. The substance, not yet accurately studied, which effects this change of color, is designated by the general term *coloring matter;* it is soluble in water, as is evident from the last-mentioned property.

Experiment. — Mix twenty drops of sulphuric acid with three ounces of water, and pour this acid water upon a potato cut in thin slices; after standing twenty-four hours, the slices are to be taken out, and washed with water till they have no longer an acid taste, and then dried. During this process the potatoes lose their *juices*, and also their albumen and coloring matter, and after drying form a solid, mealy, white, and tasteless substance, which swells up and becomes soft when boiling water is poured upon it. Potatoes dried without this treatment become gray and horn-like, and acquire an unpleasant smell.

452. *Peas.* — *Experiment.* — Pour a handful of peas into a capacious vessel containing water, and let it stand for some days in a warm room; a great part of the water is absorbed by the peas, causing them to swell up, and finally to become so soft that they can easily be mashed between the fingers. When in this state bruise them in a mortar, and add sufficient water to form with them a thin paste, which may be squeezed out by means of a linen cloth. Here, also, we obtain, as from potatoes, — 1. a *fibrous substance*, which remains on the cloth; 2. starch, which is deposited, after standing, from the turbid liquid; 3. *vegetable albumen*, when the decanted liquid is heated to boiling.

Experiment. — When you have separated, by boiling and filtering, the vegetable albumen from the above-mentioned liquid, add to the latter a few drops of some kind of acid; a flaky white body will once more be deposited; this is called *vegetable caseine* (cheesy matter), on account of its great similarity to the cheese contained in milk (animal caseine) in its constitution and also in its properties. Vegetable caseine, like vegetable albumen, contains *nitrogen;* but it is distinguished from the latter by this, namely, that it is not *coagulated* by boiling, though it is *by acids.* It occurs in the juice of many plants, but it is most abundant in the seeds of leguminous plants; potatoes, likewise, contain small quantities of it.

453. *Wheat Flour.* — *Experiment.* — Moisten a *handful of wheat flour* with sufficient water to form a stiff

paste when triturated in a mortar; inclose it in a piece of thick linen, and knead it frequently, adding water as long as the liquid which runs through continues to have a milky appearance. After standing some time, a white powder will settle from the turbid water: this is *wheat starch.*

Starch is one of the principal constituents of flour, as indeed of all sorts of meal; the second constituent remains behind in the cloth, mixed with vegetable fibre, and is a viscous, tough, gray substance, which has received the name *gluten* (vegetable fibrine). The gluten only swells up in water, without being completely dissolved; in its constitution it corresponds exactly with albumen, and, like this, contains *nitrogen.*

When the water decanted from the starch is boiled, it becomes turbid, and when partially evaporated yields a flocculent precipitate; thus wheat meal contains also some *vegetable albumen.*

454. If the results of these experiments are grouped together, we shall find that there are always present in potatoes and peas, and also in wheat flour, the two non-azotized substances vegetable tissue and starch, and also one or several of the azotized compounds vegetable albumen, caseine, and gluten.

Non-Azotized Substances.

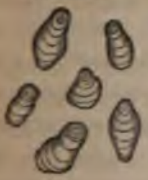
In potatoes : vegetable tissue, starch ;
In peas : vegetable tissue, starch ;
In wheat : vegetable tissue, starch.

Azotized Substances.

In potatoes : vegetable albumen (caseine) ;
In peas : vegetable albumen, caseine (much) ;
In wheat : vegetable albumen, gluten (much).

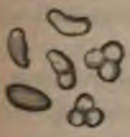
The three substances above named, containing nitrogen and sulphur, have the general name of *albuminous compounds*; hitherto they have been called *proteinaceous compounds*. Small quantities of one or more of them occur in the sap of every plant.

Fig. 181.



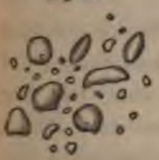
455. *Potato starch* exhibits, under the microscope, the form of egg-shaped grains, consisting of many scales overlapping each other; it glistens in the sun, is hard to the touch, and has always more of a pulverulent than of a concrete character.

Fig. 182.



In the *starch of peas* many of the grains are concave in the direction of their length, while others seem to be formed by the growing together of several globules.

Fig. 183.



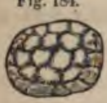
Wheat starch consists of dull, flattened, lenticular grains, which, when moist, readily adhere to each other, on which account the wheat starch of commerce always comes in loose lumps. When ground, it is known under the name of *hair-powder, &c.*

Arrowroot is a starchy meal used in medicine, which is prepared in the East and West Indies from the roots of some marsh plants.

456. *Experiment.*—If some starch is placed in a ladle, and gently heated with constant agitation till dried up, hard, horny granules are obtained, which swell when boiling water is poured on them, and become gelatinous and translucent; these granules are called *sago.* The genuine sago comes from India, where it is prepared from starch, which is extracted from the pith of many of the palm-trees.

We find the starch granules swollen by water, also, in boiled potatoes. One pound of crude potatoes contains about three quarters of a pound of watery juice, and from two ounces to two and a half of starch; at the heat of boiling water or steam, this juice is absorbed by the starch, so that the swollen grains fill up the cells, which thereby acquire a round shape. The annexed figure represents the magnified reticulated cells caused by the coagulated albumen of the juice, which fills up the interstices between the single granules. All our baked food contains starch as its principal ingredient, and owes to it its friable and light character.

Fig. 184.



457. *Experiment.* — Heat in a vessel half a dram of starch, with an ounce or an ounce and a half of water, constantly stirring it till it boils; the mixture first becomes slimy, and finally as thick as a jelly. The grains of starch absorb water, and swell up, so that the single membranes break open. This swollen starch is well known for its adhesive properties, and is variously employed as a means of thickening printing colors. When linen and other woven fabrics are passed through a thin paste of starch, they acquire, after drying, a degree of stiffness, and by ironing or strong rubbing and pressing a bright gloss (dressing). The swelling of many of our most common articles of food, such as rice, groats, barley, beans, peas, lentils, &c., when boiled with water, is now readily explained by their containing a large quantity of starch.

Experiment. — If you let some starch paste remain for a length of time in a warm place, it gradually becomes thin and sour; it thus passes into a peculiar acid, which has received the name of lactic acid. The same acid is produced when milk becomes sour, and it imparts to curdled milk and to buttermilk their well-known sour taste.

Experiment. — Dilute some starch paste with a large proportion of water, and add to it a few drops of tincture of iodine (§ 155); an intensely deep *blue* liquid (*iodide of starch*) is produced. The same color may be perceived by dropping some tincture of iodine upon meal, potatoes, carrots, &c. We have in iodine an extremely delicate test for starch.

There is a peculiar species of starch called *inuline*, which occurs in the roots of the elecampane and the dandelion, and in the bulbs of the dahlia; this is colored yellow by the tincture of iodine.

Another variety of starch, which is colored brown by the tincture of iodine, is found particularly in Iceland moss, and is called *lichenine*.

Change of Starch into Gum and Sugar.

458. *Starch Gum.* — *Experiment.* — If starch is heated in a ladle over a gentle alcohol flame, and during the heating (roasting) is constantly stirred to prevent its burning and baking on the bottom of the ladle, it acquires after a while a yellow, and finally a brownish-yellow color, and then possesses the new property of dissolving, both in cold and in hot water, into a mucilaginous liquid. (Common starch is entirely insoluble in cold water, and only swells up in hot water.) Starch thus transformed is called *roasted starch*, *starch gum*, or *leïocome*. It is well adapted for the thickening of colors and mordants in calico-printing, and therefore is now often made on an extensive scale, usually by roasting starch in large coffee-roasters.

Experiment. — Mix thoroughly, in a small dish, half an ounce of starch with one dram of water and four drops of nitric acid; let the mixture dry in the air, and then place it on the hearth of a heated oven, which is just hot enough to hiss feebly when touched with the moistened finger. After some hours, all the nitric acid will be expelled, and the starch will dissolve almost entirely in cold water, and completely in hot water. *Starch-gum* thus made is white, or has only a slight yellowish tinge.

Experiment. — Make a paste of potato starch by boiling starch with water, and, while yet hot, add to it, in a saucer, some drops of sulphuric acid, with constant stirring. That this acid effects a change is evident, for the viscid mass very soon becomes a thin liquid. Now place the saucer on a jar, in which some water is simmering (steam-bath), and let it remain over the hot steam (the contents of the saucer not being heated quite to the boiling point), until the liquid has become semi-transparent. When this is the case, add prepared chalk by small portions at a time to the liquid, until it ceases to give an acid reaction, and after having filtered it from the gypsum, leave it to evaporate in a warm place. The dry residue has an amorphous, vitreous appearance, an insipid taste, and dissolves in water, forming a transparent viscid fluid; it is not soluble in alcohol. Vegetable substances with such properties are usually called *gums;* the gum obtained from starch has received the special name of *dextrine.*

Fig. 185.

459. *Starch-Sugar.* — *Experiment.* — Repeat the former experiment, with the following deviation. Bring to brisk boiling two ounces and a half of water, to which twenty drops of sulphuric acid have been add-

ed, and then add one ounce of starch mixed with a little water, forming a paste, but only in small quantities at once, that the boiling may not be interrupted. When all the starch is stirred in, let the mixture boil for some minutes, then neutralize the acid by chalk, and evaporate the filtered liquid to the consistency of a thick sirup. It possesses a very sweet taste, and consists of a solution of sugar in water. The *starch-sirup* thus made, as well as the white, solid *starch-sugar*, easily prepared from it, are now both articles of commerce.

Starch, as shown by these experiments, is converted by sulphuric acid, on moderate heating, into gum; on stronger heating, into sugar. In the latter case, also, dextrine is first formed, but this soon passes over into sugar. Accordingly, sulphuric acid exerts two different actions. By the first action, the starch becomes *gum* (dextrine). By the second action, the dextrine becomes *sugar*.

It has not yet been explained how this effect is produced. Starch, starch-gum, and starch-sugar have each the same constitution (isomeric), so that their difference undoubtedly depends upon a different arrangement of the atoms of carbon, hydrogen, and oxygen contained in them, and it is undoubtedly the sulphuric acid which effects this change in the position of the atoms. No portion of the sulphuric acid has been decomposed, neither has any of it combined with the organic substance; for we find again, in the gypsum formed, exactly the same quantity of sulphuric acid that had been originally employed. Accordingly, in this case it exerts an action quite different from the usual action; it is an action like that of spongy platinum, which can *excite a chemical activity* in another substance, without itself undergoing any change. This peculiar mode of action of sulphuric acid and of platinum is often designated by the name of "action of *presence*" (contact), or action by *catalysis* (power of conversion).

460. *Malt and Diastase.* — *Experiment.* — Pour two ounces of lukewarm water upon a quarter of an ounce of coarsely pulverized barley-malt; let the mixture remain some hours near a fire or stove, or in the sun, and then strain it through a linen cloth; there is found in the filtrate a substance not yet well known, called *diastase*, by means of which the starch may be converted into *gum* and *sugar* in the same way as by sulphuric acid.

Experiment. — Rub a quarter part of the diastase with some hot starch paste, made of a quarter of an ounce of potato starch and two ounces of water; heat the mixture moderately (but not above 65° C.), until the paste is formed into a thin, transparent liquid. Now boil this liquid for some time at a stronger heat, strain through a cloth, and let it evaporate in a warm place. The mass remaining behind is like that obtained at § 458, and consists of *dextrine*, or starch-gum.

Experiment. — Treat the other three quarters of the diastase in the same way, but prolong the heating for several hours, which may be most conveniently done on the hearth of a stove or fireplace, applying to the liquid a heat not above 70° or 75° C. Here also dextrine is the first product formed; but this is soon converted on further boiling into starch-sugar, as may easily be perceived by its taste. By evaporation, sirup of starch is obtained, as in § 459.

461. The remarkable change which malt communicates to starch is to be ascribed to the *diastase* contained in the malt. This substance obviously acts in a

very similar manner to sulphuric acid, but its mode of action is as yet likewise unknown. At 100° C., consequently, on boiling the liquid, the effect of the malt (diastase) is destroyed. The process of forming sugar by means of the diastase of malt is of great importance to the brewer and brandy-distiller, as in the manufacture of beer from barley or wheat, or brandy from rye and potatoes, the starch of these substances must always be previously converted into sugar, before fermentation and the consequent formation of alcohol can take place. In both cases it is the diastase of the malt, indispensable in brewing and in the distillation of brandy, which effects this change in the so-called *mashing process.*

462. The taste of *malt* is sweet and mucilaginous, because the conversion of the starch into dextrine and sugar commences during germination, the further progress of which is arrested in this case by drying. If the germinated barley is allowed to continue growing, as it does in the open fields, all the starch gradually vanishes from the grain, and passes, in the form of dextrine and sugar, into the juice of the young plant, as is obvious from the sweet taste of the latter, and from its mucilaginous feeling when rubbed between the fingers.

A similar metamorphosis is also clearly to be perceived in the potatoes. The quantity of starch contained in one hundred pounds of the same kind of potatoes has been found to be, in August, 10 pounds; in September, 14; in October, 15; in November, 16; in December, 17; in January, 17; in February, 16; in March, 15; in April, 13; in May, 10. Accordingly, the quantity of starch in potatoes increases during the autumn, remains stationary during the winter, and in the spring, after the germinating principle is excited, it diminishes. It is a well-known fact, that on germination potatoes become soft, mucilaginous, and afterwards sweet; the dextrine forming from the starch renders them mucilaginous, and the sugar forming from the dextrine renders them sweet. This process of transformation advances still further in the earth, the potatoes becoming constantly softer and more watery, and when the starch is completely consumed in the growth of the young plant, the process of decay commences, and its products, carbonic acid, water, and ammonia, may be regarded as food for the somewhat older plant.

463. Unripe apples and pears are colored blue by tincture of iodine; consequently they contain starch. When completely ripe, they cease to give this reaction; therefore starch has disappeared on ripening, as appears by the taste of the fruits; they are sweet, and we must therefore presume that here also a transformation of the starch into dextrine and sugar has taken place. It appears, also, that frost is capable of exerting a similar influence upon these vegetable substances, which are rich in starch; it is well enough known, that frozen potatoes, apples, medlars, &c. have a sweet taste after being thawed.

III. GUM AND VEGETABLE MUCUS.

464. It has already been explained, when speaking of dextrine, what kind of vegetable matter is called *gum*, and likewise that it is an intermediate substance between starch and sugar. Dextrine is one of the most

widely diffused substances in the vegetable kingdom, since we find it in greater or less quantities in the juice of every plant.

But there exist in many plants certain sorts of gum, and sometimes in such abundance, that they exude from the bark as a viscid liquid, and harden upon it in transparent globular masses, such as we see on our peach and cherry trees. The name *resin*, by which these dried vegetable juices are frequently designated, is erroneous, because by resins are meant those vegetable juices which do not dissolve nor soften in water, but are soluble in alcohol. The action of gum is different; this is insoluble in alcohol, but is softened and dissolved by water.

465. *Gum Arabic.* — The best known of these peculiar sorts of gum is gum Arabic, which exudes spontaneously from several species of acacia in Africa. The finer sorts of it are white, the more common kinds have a yellow or brown color. When well dried, it is so hard and brittle that it may be reduced to a powder by pounding.

Experiment. — Pour two drams of cold water on one dram of gum Arabic, and occasionally stir the mixture; the gum will, after a few days, entirely *dissolve* in the water, forming a viscid transparent *mucilage*, which may be diluted at pleasure with more water. This mucilage has great adhesiveness, for which reason it is often used, instead of paste or glue, for joining together paper, &c., or for converting a pulverulent substance into a coherent mass (crayons, pastilles, &c.); it has, moreover, a thick consistency, and hence is variously employed in calico-printing as a thickening material for colors and mordants, and in finishing and dressing operations. A variety of gum obtained from the shores of the Senegal, whence it has been called *gum Senegal*, is peculiarly well adapted for the latter purpose, as it yields a thicker mucilage than the common gum Arabic.

Experiment. — Pour some drops of mucilage of gum Arabic into alcohol; they will not mix with each other, as the gum is insoluble in alcohol. If the mucilage is previously mixed with water, forming a thin clear liquid, and is then added to the alcohol, a turbidness ensues, and afterwards a flaky precipitate will subside; accordingly, alcohol may be used for removing gum from those liquids which contain gum.

In a chemical sense, only those sorts of gum are designated by the name of *gum* which dissolve completely in cold water, and thus form a clear, transparent liquid.

466. *Gum tragacanth* is also a vegetable exudation, well known as a stiffening material, and as forming with water an adhesive paste; it exudes from the tragacantha, a shrub which grows in Greece and Turkey, and it occurs in commerce in the form of white, tortuous filaments, or bands.

Experiment. — Let a piece of tragacanth remain for some days in cold water; it will soften and swell into a stiff, viscid jelly; a single dram of it is sufficient to convert one pound of water into a thick mucilage. The tragacanth does not dissolve, but, like starch, only *swells up;* if the mucilage is boiled, the mass becomes more uniform, but a complete solution is not effected.

This kind of gum has been called *vegetable mucus* (bassorine), to distinguish it from the former; it occurs also in many other plants, as, for instance, in the leaves of the mallows and the coltsfoot, in the roots of the althea and salep, in flax and quince seeds, and in carrageen, &c. This mucilage abounds in the cores of the quince, for it surrounds the seeds as a whitish, transparent substance; it must obviously be very plentiful, since one dram of quince-cores is sufficient to convert half a pound of water into a thick mucilage.

467. *Experiment.* — If you pour a large quantity of water upon some of the *gum of cherry or plum* trees, part of the gum will be dissolved after some time, but a part will remain undissolved as a turgid mass (vegetable mucus, cerasine). These two vegetable exudations must accordingly be regarded as mixtures of gum and vegetable mucus.

468. *Pectine.* — The juices of many fruits and roots, for instance, currants, gooseberries, cherries, apples, carrots, &c., contain a peculiar kind of mucus, which communicates to the juice the property, especially when previously boiled with sugar, of hardening into a gelatinous mass after cooling. This mucus, to which the stiffening of the juice is to be ascribed, has received the special name of *pectine* (vegetable jelly).

IV. SUGAR (SACCHARUM).

469. *Sugar of Starch.* — The manner of converting starch into sugar has already been described under the head of Starch. This sugar may be prepared in two ways; either by boiling with diluted sulphuric acid (sirup of starch), or by digesting the starch with malt or diastase (malt sirup). Both of these sirups may be regarded as concentrated solutions of sugar in water. If a *very concentrated sirup* of starch is allowed to remain

standing for some time, a granular sediment separates from it, while a part of the solution of sugar remains fluid and ropy. The solid sugar thus obtained, which consists of fine granules, is called *starch-sugar*, and the liquid portion, which, even on being evaporated to dryness, always again attracts moisture and deliquesces, is called *liquid sugar.*

Honey bears a strong resemblance to starch-sugar. If it is kept for some time after being melted, the mass, at first homogeneous, likewise separates into two parts, into a granular solid residue, and into a sirupy liquid. The former consists of starch-sugar, the latter of liquid sugar.

This species of sugar (starch-sugar) is formed also in many vegetables, and is especially abundant in fruits; as, for example, in plums, cherries, pears, figs, grapes, &c. The white coating of prunes and the white, sweet grains in raisins consist of it. On account of this origin, sugar of starch is also called *grape-sugar.*

If you taste a dried granule of sugar from a raisin, and then a little common sugar, you will at once perceive that the former is much *less sweet* than the latter; one ounce of common sugar has the same sweetening capacity as two ounces and a half of grape-sugar. The solubility of these two varieties of sugar in water is likewise very different, grape-sugar dissolving in it much less readily and more slowly than common sugar. While one ounce of cold water can dissolve three ounces of common sugar, it is able to take up only two thirds of an ounce of grape-sugar; the solution of sugar (sirup) prepared from the former is, accordingly, of a much stronger and more tenacious consistency than that prepared from grape-sugar.

470. Cane-Sugar. — Our common sugar is different from those kinds of sugar just described; it is either prepared in the tropical regions, from the juice of the sugar-cane (cane-sugar), or in France and Germany, from the juice of the beet (beet-sugar).

The operations whereby this sugar is obtained on a large scale are the following:—

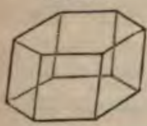
1. *Expressing* the juice from the sugar-cane or the rasped pulp of the beet, either by strongly squeezing, or by hydrostatic pressure.

2. *Boiling down* the juice with the addition of lime, by which several foreign substances are precipitated, until it acquires the consistency of a thick sirup; on cooling, the crude sugar is deposited from it, in brownish-yellow crystalline grains (*raw sugar*, or *Muscovado sugar*). The liquid sugar which does not crystallize is allowed to drain off, and forms the well-known *brown sirup* (molasses).

3. *Refining* the raw sugar, that is, the removal of the brown sirup still adhering to it. This is done,—*a*), by redissolving the raw sugar in a little water; *b*), by filtering the brown solution through coarsely-ground animal charcoal, which retains the coloring matter; *c*), by evaporating the clarified solution in vacuum pans. The concentrated sirup is then allowed to cool in moulds of a conical shape, stirring it frequently to disturb the crystallization; a solid mass, consisting of small fragmentary crystals, the common *loaf-sugar*, is obtained, from which the remaining liquid sugar is removed by letting a concentrated solution of crystallizable sugar gradually percolate through (*liquoring*). The thoroughly purified and glistening white sugar is called refined loaf-sugar; that which is not so completely clarified, and has a yellowish tinge, is the *common loaf-sugar.*

Experiment. — Dissolve half an ounce of sugar in a quarter of an ounce of hot water; the viscous solution is called *white sirup.* If this solution is put in a cup, and set aside in a warm place, and evaporated slowly, the sugar will separate from it, crystallizing in oblique six-sided prisms. In a similar manner white *candy* is prepared on a large scale from refined sugar, brown candy from raw sugar. As the crystals deposit more readily on substances having a rough than on those having a smooth surface, fine threads or pieces of wood are stretched across the vessels containing the sirup, and they soon become coated with crystals.

Fig. 186.



471. Cane-sugar, as already stated, has a much sweeter taste than grape-sugar; therefore, when used as a sweetening agent, it possesses a far greater value than the latter. The white sugar now occurring in the market in Germany is frequently found to be composed partly or entirely of starch-sugar.

Experiment. — Put into a test-tube a piece of cane-sugar, and into another some granules of grape-sugar taken from a raisin, and pour over them strong sulphuric acid; the cane-sugar becomes black by gentle heating (it is charred), but not so the starch-sugar. An opposite reaction takes place when the two sorts of sugar are heated with a solution of potassa; the grape-sugar, but not the cane-sugar, assumes a dark color.

Experiment. — These two sorts of sugar may be more accurately distinguished from each other by the copper test. First add to the solutions of sugar some drops of a solution of blue vitriol, then some drops of a solution of potassa, and place both vessels in hot water; the liquid containing the grape-sugar assumes in a few minutes a reddish-yellow color, while that containing the cane-sugar remains blue. The grape-sugar is able to abstract from the oxide of copper half of its oxygen, whereby reddish-yellow suboxide of copper is formed (§ 354); cane-sugar is also able to effect this change, but not till after boiling, or after standing several days. The sugar is converted by the oxygen taken up into an entirely new substance, called formic acid. Grape-sugar may be distinctly recognized by this test, even in an extremely diluted solution.

472. *Liquid Sugar.*—By this very indefinite name are commonly designated all those kinds of sugar which do not yield on evaporation a solid crystalline or granular, but a vitreous amorphous mass, which on exposure to the air again attracts water, and deliquesces. This kind of sugar is commonly called sirup and molasses.

473. *Sugar of milk* is that particular kind of sugar which occurs in milk, and imparts to it its agreeable sweetish taste. It is obtained in hard, white, crystalline masses, by evaporating the sweet whey. Sugar of milk is much less sweet to the taste than grape-sugar, and requires six parts of cold water for its solution. It is well known that milk becomes sour by standing for some days; this is owing to the sugar of milk being gradually converted into a peculiar acid, called lactic acid.

474. *Mannite* is a substance resembling sugar, constituting the principal part of manna (the concrete sweet juice of some species of the ash, growing principally in Italy).

CHANGES OF SUGAR.

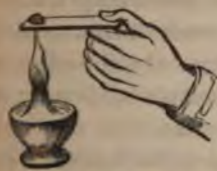
475. *a.*) *Change by Heat.* — *Experiment.* — Boil in a dish half an ounce of sugar with one dram of water, until the viscous solution begins to assume a yellowish tinge; then pour it upon a plate previously smeared with a little olive-oil. The transparent brittle mass is melted sugar in an *amorphous* state (barley-sugar or *bonbons*). The sugar is first dissolved by water; on boiling, the water is again evaporated, and the sugar passes gradually from the dissolved to the melted state. The yellowish color indicates that all the water has passed off, and that the sugar is on the point of becoming burnt.

If the transparent sugar is kept for some weeks, it becomes opaque and crystalline, when it can easily be broken up and finely comminuted. There is a scientific interest in this, as it clearly affords another illustration (§ 280) of the fact, that, even in a solid state, the smallest particles of sugar (its atoms) can change their situation with respect to each other.

Experiment. — Repeat the former experiment, but without stopping the heating on the appearance of the yellow color; the sugar will grow darker, until it finally attains a brownish-black color, and will exhale at the same time a peculiar empyreumatic odor. On cooling, it is obtained as a hard, almost black mass, which soon deliquesces in the air, forming a dark sirup, and is called *burnt sugar* or *caramel.* A couple of drops of it impart to a large vessel filled with water the appearance of Jamaica rum. On account of its strong coloring properties, burnt sugar is much used for imparting to liquors — vinegar, alcohol, &c. — a yellow or brown color.

Experiment. — When exposed to a still stronger heat, the sugar becomes charred, and finally burns up like wood, as may easily be seen by holding a piece of it on a platinum foil over an alcohol flame. The flame indicates also that inflammable gases are evolved. Pure sugar leaves *no* residue. If it contains lime, white ashes remain behind upon the foil, which do not volatilize even at the strongest heat.

Fig. 187.



476. *b.*) *Change by Acids.* — *Experiment.* — If you add a few drops of lemon-juice, or a little tartaric acid, to a thick, boiling solution of sugar, it immediately becomes a thin liquid, which does not crystallize on evaporation; thus is explained why the sweet juices of fruits, in which organic acids are always present, do not yield, on being boiled down, a solid sugar, but only a thick sirup. If you treat the solution of sugar as directed in the copper test (§ 471), you will find that it now contains grape-sugar; cane-sugar is therefore converted by boiling with organic acids into grape-sugar. This metamorphosis is produced also in various other ways, as by mere prolonged boiling of the solutions of sugar, by boiling them with diluted sulphuric acid, by fermentation, &c. If sugar is boiled for a long time with diluted sulphuric acid, it finally passes into a brown substance, resembling humus. When boiled with nitric or other acids, which yield oxygen, it oxidizes first into saccharic acid, then into oxalic acid, and finally into carbonic acid and water.

Sugar, as though it were an acid, can combine in fixed proportions with oxide of lead, lime, and many other bases; but it thereby loses its sweet taste.

RETROSPECT OF THE VEGETABLE MATTER HITHERTO CONSIDERED (VEGETABLE TISSUE, STARCH, GUM, MUCUS, AND SUGAR).

1. *Organic substances* are such chemical combinations as are formed in animals and vegetables during life.

2. But we also designate by this term those chemical combinations which are formed from animal and vegetable matter, whether they are *transformed* with or without artificial assistance (products).

3. Organic matter undergoes decomposition with *remarkable facility*. We observe such changes, —

a.) In living animals and plants (germination, ripening, &c., — respiration, digestion, &c.).

b.) In dead animals and vegetables (fermentation, putrefaction, decay, &c.).

c.) In the decay of animal and vegetable matter (charring, burning, &c.).

d.) In the treatment of organic substances with acids, bases, &c.

4. In all these changes, the form only of the organic body disappears; the elements of which they consist are unchangeable; they vanish from our sight only because they assume an aeriform shape.

5. We have not yet succeeded (with a few unimportant exceptions) in *preparing* and *imitating* the organic combinations by putting together their constituent parts; we are only able to *decompose* them, and to *convert* the elements into new bodies.

6. The four organogens, oxygen, hydrogen, carbon, and nitrogen, are the principal constituents (the elementary constituents) of all that lives and has ever lived. A few inorganic substances only are added to *them*, as sulphur, phosphorus, potassium, calcium, &c.

7. These four organogens have the power of combining in an *unlimited* manner with each other, and, indeed, not only with each other, but also with many inorganic substances; the number of the organic combinations is therefore almost infinite.

8. Thus, since the difference of organic matter cannot, as in inorganic substances, consist in the number of the constituents, so the cause of this difference must be sought for in the varied juxtaposition or *grouping* of these constituents (*compound radicals*).

9. *Vegetable tissue*, *starch*, *gum*, *mucus*, and *sugar* are among the most widely diffused of the groups of atoms (or proximate constituents) occurring in the vegetable kingdom. They are present in all plants.

10. They have neither acid nor basic properties, and are therefore called *indifferent* vegetable bodies.

11. There is a very great similarity in their constitution; namely, they consist of only three elements, *carbon*, *hydrogen*, and *oxygen* (they are non-azotized); and, moreover, they contain oxygen and hydrogen always *in the same proportions as in water*, namely, in equal atoms.

12. These four proximate constituents of the vegetable kingdom form a *principal ingredient of all our vegetable food;* they perform, accordingly, a very important part in the process of animal life.

V. ALBUMINOUS SUBSTANCES (AZOTIZED AND SULPHURIZED SUBSTANCES).

ALBUMEN, CASEINE, AND GLUTEN.

477. UNDER the head of Vegetable Tissue, when speaking of the preparation of starch, it has already been shown what is to be understood by vegetable albumen, caseine, and gluten, and that all plants contain in their juice one or more of these azotized substances.

Vegetable albumen is soluble in water, but is rendered insoluble by *boiling* (it coagulates). It is found particularly abundant in culinary plants and in oily seeds, as in almonds, rape-seed, flax-seed, poppy seeds, &c.

Vegetable caseine is likewise soluble in water, yet it does not coagulate by heat, though it does by adding an *acid* to a solution of it. The leguminous plants, such as peas, beans, lentils, &c., are very rich in it.

Gluten (vegetable fibrine) is insoluble in water, and forms an essential part of wheat.

Experiment.—Add to one dram of bruised peas half a dram of caustic potassa and one ounce of water, and boil the mixture till a drop of the liquid causes a brown spot on lead-paper (paper which has been moistened with a solution of sugar of lead). The dark color produced on the lead-paper is owing to the formation of sulphuret of lead; it indicates that *sulphur* from the peas has been rendered soluble by the potassa. By now adding a few drops of sulphuric or muriatic acid to the liquid, the presence of the sulphur also makes itself known by the smell, since sulphuretted hydrogen gas is evolved (§ 213). Vegetable albumen and gluten, when thus treated, give rise to the same phenomena. The tarnishing of silver spoons on remaining for some time in boiled peas, &c., is now simply explained, as sulphuret of silver has been formed on the surface. Vegetable albumen (likewise animal albumen) contains, besides sulphur, a small quantity of phosphorus.

It has hitherto been assumed, that a common fundamental body (an organic radical) was contained in the albuminous substances, which was called *proteine;* but more recent investigations have shown that such an organic element does not exist.

478. It has been ascertained by careful experiments, that the chief proximate constituents of animal matter have the same constitution as the albuminous substances of the vegetable kingdom, and this has led to the conclusion, that the component parts of the bodies of those animals whose food consists entirely of vegetables are derived from these albuminous substances. This conclusion is most fully confirmed by the constitution of the blood, the component parts of which are albuminous matter (albumen and animal fibrine). Now, as the blood is the medium of nourishment, the blood being first formed from the food, and afterwards all the other parts of the animal body from the blood, so we may fairly infer that from the albumen, caseine, and gluten which we receive in the form of bread, peas, &c., the albuminous substances of the blood are formed, and from these the other parts of the body. For this reason, articles of food are esteemed nutritive in proportion to the amount of nitrogen they contain.

CHANGE OF ALBUMINOUS SUBSTANCES BY DECAY AND PUTREFACTION.

479. *Formation of Ammonia.* — *Experiment.* — Put some *gluten, some coarse* meal, or some peas, into a

flask, pour in some water, and connect the flask by means of a glass tube with a second flask, filled about an inch deep with water, and let them remain in a moderately warm place. Insert, also, between the cork and the neck of the first flask, a strip of lead-paper, in such a manner that part of it shall hang down into the flask. The following changes will be observed to take place, more rapidly at a warm, more slowly at a cold temperature: —

a.) Bubbles of gas escape from the glass tube into the second flask; they consist of *carbonic acid* (and some hydrogen), as may be seen by the turbidness which follows on the addition of lime-water.

b.) The lead-paper is colored dark, a sign of *sulphuretted hydrogen* being generated.

c.) A pungent smell of ammonia is evolved from the liquid standing over the gluten, when it is heated with lime or potassa; consequently *ammonia* has also been formed.

If we compare this process of decomposition with that which takes place on the putrefaction of non-azotized substances (§ 445), we shall observe the following principal difference in the result: — *On the putrefaction of albuminous substances, their nitrogen and sulphur (and phosphorus) combine with hydrogen, forming ammonia and sulphuretted hydrogen (and phosphuretted hydrogen).* These aeriform substances are the chief cause of the very disagreeable odor which is given off during the decay or putrefaction of azotized substances, — for instance, animal substances. During the progress of this decomposition, there is formed also, as in ligneous fibre, a brown substance resembling humus.

However disgusting may be the products of putrefaction and decay, they nevertheless contain within themselves the germ of the most beautiful compounds; the most beautiful plants arise from such products of decay. Indeed, the most nauseous-smelling decaying azotized substances are the most powerful means of rendering our fields and gardens fertile (the best manures).

480. *Formation of Nitre.* — *Experiment.* — Mix some flax-seed meal with wood-ashes, sand, and lime, and let this mixture remain exposed to the air for several months in the summer season, frequently moistening it with water, and stirring it. If the mixture is then treated with hot water, and the solution evaporated, prismatic crystals will be formed from the latter on cooling, which will detonate smartly when thrown upon glowing coals; they consist of *nitre* (§ 207).

Here, also, ammonia is in the first place formed from the nitrogen of the vegetable albumen, present in great abundance in the flax-seed meal; but it is induced by the predisposing influence of the strong base to undergo still further putrefaction, that is, to attract oxygen from the air, whereby water is formed from its hydrogen, and nitric acid from its nitrogen, the latter of which combines with the potassa and lime.

$$\begin{array}{rcll} \text{From ammonia} & = & N & H_3 \\ \text{and oxygen} & = & O_5 & O_3 \\ \hline \text{are formed nitric acid and water} & = & NO_5 + & 3HO. \end{array}$$

In a similar manner nitre is often generated in arable land, whence it passes into the juice of plants; thus it is known that beets and tobacco growing upon very strongly manured soil, and also those rank plants growing on manure-heaps, such as henbane, thorn-apples, &c., are frequently so rich in nitre, that when dried they emit sparks, if burnt on charcoal.

481. *The extraordinary* facility with which albumi-

nous substances undergo *decomposition*, when they are exposed to the air in the moist state, is explained very simply by the fact that they contain five, indeed, six elements, and always several atoms of each, as component parts (§§ 425, 429). If during their decomposition they come in contact with non-azotized substances, these also are induced to enter into decomposition,—they are, as it were, infected. There follows in this connection that important change which *sugar* experiences when it is brought in contact with albuminous substances in a state of decomposition. This metamorphosis, known under the name of spirituous fermentation, will be more particularly considered in the following pages.

RETROSPECT OF THE ALBUMINOUS SUBSTANCES (ALBUMEN, CASEINE, GLUTEN).

1. The albuminous substances are characterized by containing, not only carbon, oxygen, and hydrogen, but also *nitrogen* and *sulphur*.

2. On account of this complex nature, *they are decomposed with the greatest ease* (fermentation, putrefaction, decay).

3. If while they are decomposing they come in contact with other organic substances, they cause these also to enter into fermentation, decay, putrefaction, &c.

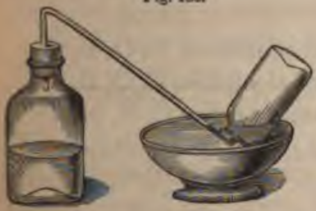
4. All vegetables contain, though not always in great quantity, one of these substances; from this universal diffusion, we infer that it has an important office to discharge;

5. Which office consists undoubtedly in this, that by means of it the growth and nourishment of plants may be brought about.

VI. CONVERSION OF SUGAR INTO ALCOHOL (ALCOHOLIC FERMENTATION).

482. *Experiment.* — Half an ounce of honey is dissolved in four ounces of water, and some of the gluten or caseine from experiment § 479, in a state of decomposition, is added to it; the liquid is then put in a moderately warm place (18° to 24° C.), when it soon enters into fermentation, with the evolution of a large quantity of gas. If you perform the experiment in a flask furnished with a bent glass tube, one end of which is passed under a second flask, filled with water, which is inverted over the pneumatic trough, the gas may easily be collected; it consists of carbonic acid. If the liquid still retains a sweet taste after the evolution of the gas has ceased, then add another portion of the gluten to it, whereby the fermentation is again renewed. Finally, all the saccharine taste will have disappeared, and the liquid will have acquired a spirituous flavor. The fermented liquor is called *metheglin;* instead of sugar it contains *alcohol*, and this is the reason of its intoxicating effect. A portion of the gluten is found at the bottom of the vessel, converted into a brownish residue.

Fig. 188.



All albuminous matter in a state of decomposition, as, for instance, old cheese, putrefying flesh, blood, &c., acts like putrefying gluten; but the substance which possesses this fermenting power in the highest degree is the altered gluten of barley, obtained in great quantity as a secondary product in the brewing of beer (surface yeast, or brewer's yeast). All substances which are able to excite fermentation in solutions of sugar are designated by the term *ferment*. Surface yeast (§ 488) is accordingly the most powerful ferment.

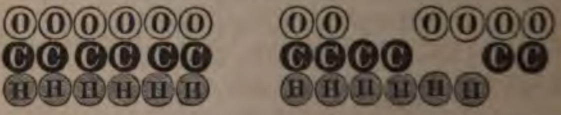
Experiment. — Repeat the former experiment, adding, instead of the gluten, a teaspoonful of yeast to the honey-water; the process of fermentation will now proceed much more rapidly and regularly.

483. The change which the sugar experiences during this process may be rendered very intelligible by comparing together the formulas of sugar, alcohol, and carbonic acid.

1 atom of honey or grape-sugar consists of $C_6\,O_6\,H_6$;
from this are formed 1 atom of alcohol $= C_4\,O_2\,H_6$,
and 2 atoms of carbonic acid $= C_2\,O_4 = 2CO_2$.

Alcohol and carbonic acid, added together, yield again the constituents of sugar. *Thus sugar is resolved by fermentation into alcohol and carbonic acid.*

Fig. 189.



Grape sugar. Alcohol. Carbonic acid.

Both substances did not previously exist in the sugar, but they are new products of a peculiar decomposition of the sugar, — peculiar for this reason, that they are exclusively made up of the elements of the sugar, without any thing being either subtracted from it or added to it. The ferment works also in the same peculiar manner; it induces a decomposition of the sugar, yet without combining with the sugar, taking any thing from it, or giving any thing to it; its mode of operation is analogous to that of sulphuric acid, when the latter converts starch into sugar (§ 459). The action of the ferment, however, differs from that of sulphuric acid just alluded to, since the ferment itself does not remain unchanged, but is also decomposed during the fermentation. Accordingly, two sorts of changes are going on by the side of each other in the fermenting liquids; — 1.) that of the azotized ferment; 2.) that of the non-azotized sugar. The ferment always commences the change, which is continued in the sugar, as if the latter were infected. The process is very similar to what occurs in the case of a fresh apple, which begins to rot on coming in contact with one already in the act of rotting.

Experiment. — Instead of honey, take a solution of white sugar, and add some yeast to it; in this case the fermentation will not take place so soon, since the cane-sugar must pass into grape-sugar before its decomposition into alcohol and carbonic acid can commence. This transition takes place simply by the addition of one atom of water; for if one atom of water is added to the cane-sugar, $= C_6 H_5 O_5$, there is formed $C_6 H_6 O_6$, or grape-sugar.

WINE.

484. All *sweet vegetable juices* pass *spontaneously* into fermentation without the necessity of adding to them a ferment, because they always contain sugar and one of the albuminous substances, as albumen, caseine, or gluten.

Experiment. — Submit freshly expressed beet-juice to a temperature of about 20° or 25° C.; the juice will soon effervesce, deposit a sediment, and be converted into a spirituous liquid (beet-wine).

In the same manner currant and gooseberry wines are prepared from currants and gooseberries, cider from apples, the so-called cherry-water by fermenting and afterwards distilling the cherry-juice, rum by fermenting and afterwards distilling the juice of the sugar-cane, &c.

The most common of all the fermentations of this kind is the fermentation of the grape-juice, wine being the result. In order to prepare *clear* wine, the grapes are pressed, the juice (*must*) is poured into vats and allowed to remain in them in the cellar, where, as the temperature is tolerably low, the fermentation proceeds so slowly that it is not completed until after some months. The young wine is racked off from the lees, and poured into fresh vats; it still contains a small quantity of sugar and albuminous matter, which are both gradually converted, the former into alcohol and carbonic acid, the latter into lees (*after fermentation*). In the manufacture of *red wine*, the purple grapes are bruised, and then fermented, together with their skins and stalks; a red coloring matter is extracted from the skins, and tannin from the stalks and seeds, the tannin imparting to this species of wine its favorite astringent taste. *Sparkling* wine (Champagne) is made by letting the fermentation proceed in corked-up bottles, whereby the carbonic acid formed is retained in the wine.

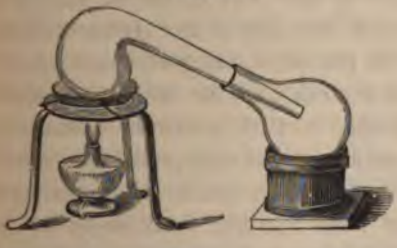
485. The grapes growing in *northern countries*, for instance, in Germany, contain proportionably more albuminous matter and tartar than sugar, which accounts for the difference in the smell and taste of wine. The taste of the German wines is not sweet, because the albuminous substances present are more than suffi-

cient to decompose all the sugar; the odor (*the flower or the bouquet*) is peculiarly pleasant, because, the tartar being abundant, there is generated during the fermentation a volatile substance (*œnanthic ether*), which possesses a very agreeable odor.

It is different with the grapes of the more *southern countries*, as Greece, Spain, Portugal, &c. Here, in consequence of the higher temperature, the grapes are richer in sugar, but poorer in tartar and albuminous matter. In this case the latter substance is not sufficient to effect the decomposition of all the sugar during the fermentation, so that a part of the sugar remains undecomposed, and gives to the wine a sweet taste. Neither is any œnanthic ether generated, since the due quantity of tartar is wanting; consequently these wines possess no bouquet.

486. *Experiment.* — If some wine is put into a retort, and subjected to distillation at a moderate heat, at first the more volatile alcohol, together with the œnanthic ether, will pass over. A very agreeable smelling spirit is thus obtained, known in commerce under the name of *Cognac*, or *French brandy*. In the wine countries, the lees remaining after the wine is racked off are generally used for this purpose, since, in the swollen, pap-like state into which they settle in the vats, they retain mechanically a large quantity of wine.

Fig. 190.



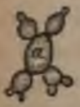
BEER.

487. Next to wine, *beer* and *brandy* are the most important fermented liquors. The manufacture of them differs essentially from that of wine in this respect; that materials are employed which contain no sugar already formed, but instead of it *starch*, such as barley, wheat, rye, potatoes, &c. Starch cannot, like sugar, be resolved directly into alcohol and carbonic acid; and, when employed in the manufacture of alcohol, it must previously be converted into sugar. This, in the present case, is always effected by the diastase of the barley-malt in the so-called mashing process of the brewers and brandy-distillers (§ 461).

Experiment. — Pour a mixture of an ounce and a half of cold water and two ounces of boiling water upon half an ounce of bruised malt, and set it aside for some hours in a warm place, where it will reach a temperature of about 65° or 75° C.; a sweet liquid is thus obtained, composed, not only of dextrine and sugar, but containing also the gluten, thereby rendered soluble, which was present in the malt. The brewer calls this liquid the *wort*. Strain it with pressure through a cloth, and boil the liquid for some time, until it becomes clear and transparent; then let it cool to 30° C., and add to it a teaspoonful of yeast; it will soon begin to ferment, and after some days will clarify again; the *clear*, fermented liquor is *beer*. This is the mode of making the *Berlin white* or *pale beer*, which is not bitter. If during the boiling some hops (female flowers of the hop-vine) are added to the wort, an aromatic bitter substance is dissolved from them (*lupulin*), which not only imparts to the beer a pleasant and bitter taste, but also a greater body.

488. What is particularly remarkable in the above fermentation (*superficial fermentation*) is the great quantity of yeast that separates. It proceeds from the gluten of the barley, which is dissolved during the mashing process, but in the course of the fermentation is again precipitated as insoluble yeast. This is called *surface yeast*, it being raised to the surface in consequence of the great evolution of carbonic acid, and when the vats are full, it is caused to pass out through the bunghole; it is the best ferment, and the quantity obtained in the last experiment is sufficient to bring to complete fermentation the wort of a whole pound of malt. Its power of exciting fermentation is destroyed when it is rendered quite dry, or when it is boiled, or very finely triturated; and likewise by mixing antiseptic substances with it, as, for instance, alcohol, pyroligneous acid, sulphurous acid, volatile oils, &c. This yeast, when examined through the microscope, has exactly the form of simple vegetable cells (*a*); and their increase in the wort takes place in the same manner as in the most simple plants, new cells or buds developing themselves on each globule of the old yeast. These globules are hollow, filled with an azotized liquid, to which is to be ascribed the power of the yeast to excite fermentation.

Fig. 191.



New beer holds, also, some sugar and gluten in solution; therefore, like wine, it undergoes, when kept, a second slight fermentation (*after-fermentation*). If this is allowed to take place in well-stopped bottles, so that the carbonic acid cannot escape, a foaming beer (*bottled beer*) is obtained, in the same way as in the manufacture of sparkling Champagne.

But all the *gluten is not* separated, even by the second fermentation, and hence the upper fermenting (light) beer undergoes a still further change on being exposed to the air; it is the alcohol, however, which is now altered by the albuminous matter undergoing decomposition; it passes into vinegar, and the beer becomes acid.

489. *Experiment.* — Repeat the former experiment, but cool the wort below 10° C. before adding the yeast, and then let the liquid remain in a cool place; a very gradual fermentation takes place, which will not be concluded for several weeks, perhaps even months. During this process, the carbonic acid is evolved in very small bubbles, and the yeast settles at the *bottom* of the vessel (*sediment ferment*, *bottom yeast*). The beer thus prepared contains scarcely a trace of gluten or yeast, and therefore can be kept for years without becoming sour; it is, moreover, richer in carbonic acid than that obtained by the superficial fermentation process, because at the lower temperature, and by the more gradual elimination of carbonic acid gas, it was able to retain more of it. The stronger kinds of beer (*Bavarian beer*, *strong beer*, &c.) are made in this way. The thick bottom yeast, separating during this process, acts indeed as an exciter of fermentation upon the sugar, but far more slowly and gently than the frothy surface yeast.

490. The peculiarities of the two methods of fermentation may be elucidated as follows: —

Surface Fermentation	*Bottom Fermentation*
a.) takes place at a higher temperature (12 – 20° C.);	at a lower temperature (5 – 10° C.).
b.) takes place rapidly (in three or four days);	slowly (in six or eight weeks).
c.) in this case imperfect separation of the yeast by flowing over;	in this case thorough separation of the yeast by settling.
d.) surface yeast is finely divided and frothy;	bottom yeast is compact and heavy.

e.) surface yeast is a strong exciter of fermentation;	bottom yeast a feeble exciter of fermentation.
f.) surface fermented beer soon becomes sour;	bottom fermented beer does not.
g.) surface fermented beer contains but little carbonic acid;	bottom fermented beer more.
h.) serves for the manufacture of weak beer;	serves for the manufacture of strong beer.
i.) by lowering the temperature the surface fermentation may be converted into bottom fermentation.	by raising the temperature the bottom fermentation may be converted into surface fermentation.

Experiment. — Subject a weighed or measured quantity of beer to distillation (§ 486); a weak *alcohol*, together with carbonic acid, will first pass over, and finally only a watery liquid. Pour the yet fluid residue into a cup, and set it in a warm place; it dries up, forming a dry amorphous mass (*extract of beer*), which consists principally of *dextrine*, *sugar*, and the *bitter principle of hops*. By determining the strength and the quantity of the alcohol, and the weight of the extract obtained, we have the two most important factors for estimating the nature and purity of the beer.

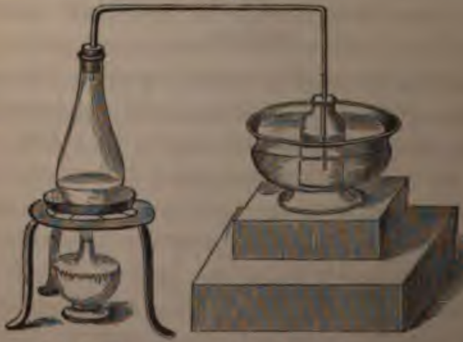
BRANDY.

491. The *preparation* of brandy is similar to that of beer, inasmuch as substances containing starch are likewise employed in the preparation of it, and as the starch must first be converted into sugar before the fermentation can proceed. This is done, as in the case of beer, by the mashing process, that is, by the operation of the diastase of the malt upon the starch. To this end either boiled and mashed potatoes or rye are mixed with bruised barley-malt and hot water, so as to form a paste, which is to be kept at a temperature of 70° C, until *a complete formation* of sugar is effected; then

brewers' yeast (surface ferment) is added to the sweet mash or wort previously cooled off, whereby fermentation is induced. When this fermentation is concluded, put the mass into a copper boiler, and distil the volatile alcohol from the non-volatile parts (husks, gluten, fibrous matter, &c.). The residue is used as a nourishing food for the fattening of cattle. Formerly simple stills were used for this distillation, and a thin spirit (*brandy* or *low wines*) was obtained, which consisted of about one third of alcohol and two thirds of water; but now a more complicated apparatus is universally employed, by means of which a brandy of double the strength is obtained (*rectified spirit*). The principle upon which this apparatus depends will be explained in the following experiment.

492. *Rectification or Strengthening of Brandy.* — *Experiment.* — Pour three ounces of common brandy into a capacious flask, and carefully distil half of it into a vessel, which is cooled by means of very cold water, or what is still better, by ice. If the brandy

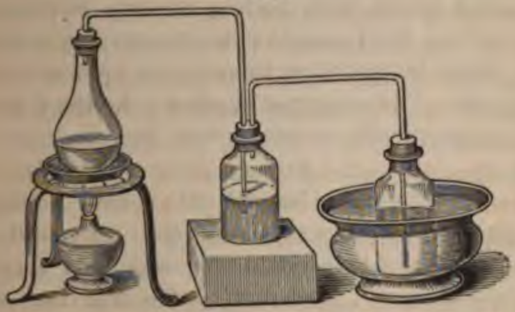
Fig 192.



contained thirty per cent. of spirit, then the ounce and a half of alcohol, first passing over, will contain at least fifty per cent. Alcohol is *more volatile* than water, therefore it first passes over, in company with a smaller quantity of the latter, while the larger quantity of the water, together with the fusel oil which might have been contained in the brandy, remains behind in the flask (*phlegm*).

493. *Experiment.* — If you connect with the flask and the receiver an intermediate vessel, a wide-mouthed vial, for instance, which is easily done by means of two glass tubes bent at right angles, and a cork perforated with two holes, and then repeat the above experiment of distillation, the alcohol vapors passing over will first condense in the middle vessel. But as this vessel is not cooled down, the liquid condensed in it will finally also boil, and the vapors thus formed will pass over into the receiver surrounded with cold water, and will there be condensed for the second time. In this manner a double distillation (rectification) is effected. The flask contains boiling brandy (at 30° Tralles*); the intermediate vessel, boiling rectified alcohol

Fig. 193.



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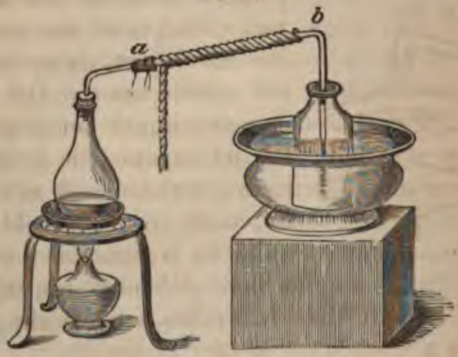
* The alcoholometer of Tralles floats to a figure on the stem, which indicates the percentage of alcohol, *by volume*, in the liquor in which it is *placed*.

(at about 50° Tralles). After the termination of the experiment, the first vessel will contain phlegm; the second, weak spirit; and the third, very strong highly rectified spirit (of 70 to 80° Tralles).

If you adapt to the corks of the first two vessels a couple of thermometers, which shall dip into the liquid, you will find that the liquid in the flask boiled at the commencement of the experiment at 85° C., and at the end of the experiment at from 95 to 100° C., while that contained in the second vessel commenced boiling at 80° C., and ended with boiling at from 85° to 90° C. It is obvious from this that a strong spirit boils at a much lower temperature than that at which weaker spirits boil. The strongest alcohol (absolute) boils at 78° C., consequently at twenty-two degrees lower than water.

494. *Experiment.* — Connect with a flask a tolerably large glass tube, which is so bent that its middle part may have a slight inclination upwards, as is shown in the annexed figure; from *b*, this tube is wound round

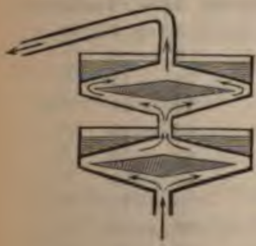
Fig. 195.



with moistened wick-yarn, the end of which hangs down at *a*. At *a*, bind a strip of cloth (several times folded together and smeared with some drops of olive-oil) round the tube, so that the water from the wick may not run down upon the flask. Now distil as before three ounces of brandy, but during the distillation continually drop cold water upon the wick-yarn, at *b*, in order to cool the vapor of brandy as it passes over. Catch the water running down the outside of the tube in a vessel placed below the end of the wick-yarn. If the distillation is arrested when about one ounce of brandy has passed over, we shall have a stronger spirit in the receiver than was obtained in the experiment in § 492, because, by the partial cooling of the vapor of the brandy, the principal part of the less volatile aqueous steam was condensed, and therefore a vapor richer in alcohol passed into the receiver, while the water condensed in the tube flowed back into the flask.

This principle of *partial refrigeration* has been most successfully applied to the distillation of brandy on a large scale. The best-known apparatus used for this purpose is called the *dephlegmator*, and is so contrived that the hot vapors rising from the still must pass through several copper channels before reaching the refrigerator; these channels have a division-wall in the centre, and are kept cold externally by a constant current of water. We obtain in this way a spirit of from 70° to 80° Tralles, while a simple still yields only a weak spirit of 30° Tralles.

Fig. 196.



495. Alcohol is rendered not only *stronger*, but *purer*, by the above-mentioned rectification. Besides alcohol,

there is formed from grain and potatoes, during f mentation, an oily, disagreeably smelling liquid, the called *fusel oil*, and also some vinegar. Both are l volatile than alcohol, and therefore, during the abo rectification, are for the most part condensed with t water, which flows back. The *phlegm* is accordin a mixture of water with alcohol, fusel oil, and vineg The alcohol may be thoroughly purified from the fu oil by letting it stand for some time in contact wi freshly burnt charcoal, and then filtering it off; the fu oil remains behind in the pores of the charcoal (§ 10

496. In the same way that brandy is made in G many from grain and potatoes, a spirituous liqu called *arrack* is prepared in the East Indies from ri by mashing, fermenting, and distilling, and mixi with it the seeds of the palm-tree, thus imparting to a peculiar flavor, and an odor resembling that of rum

497. All fermented liquors contain alcohol, and o to this their intoxicating power. The quantity of contained in our ordinary spirituous liquors is sho in the following table: —

			Pure Alcohol.	
In 100 measures	of	common beer are contained	1½ — 2	measure
"	"	strong beer,	3 — 5	"
"	"	porter or ale,	6 — 8	"
"	"	wine,	10 — 15	"
"	"	Madeira wine,	18 — 24	"
"	"	French brandy,	40 — 45	"
"	"	liqueur,	45 — 50	"
"	"	rum or arrack,	50 — 60	"
"	"	rectified spirit,	60 — 70	"
"	"	alcohol,	70 — 75	"
"	"	highly rectified alcohol,	86 — 90	"

SPIRIT OF WINE, OR ALCOHOL.

498. *Anhydrous Alcohol.* — Alcohol has as yet on

been obtained by the fermentation of sugar. In the preceding chapters we have already shown how alcohol is formed, how it is rendered stronger, and how it is purified. This is done by incomplete distillation, or by incomplete condensation, since the alcohol is more difficult to volatilize than water, and its vapor more difficult to condense than steam. But all the water cannot be separated in this way from the alcohol, as the alcohol retains one tenth part of the water so firmly that it can neither be withdrawn from it by distillation nor by cooling. In order to procure it absolutely anhydrous, a body must be presented to it which has a greater affinity for water, and fixes it so firmly, that it cannot evaporate with the alcohol at the boiling point of the latter. Such a body is quicklime.

Experiment. — Put into a flask one ounce of quicklime that has been broken into small pieces, and pour upon it one ounce of very strong alcohol; connect a receiver with the flask, as in the experiment in § 492, and let the mixture remain in repose for one day. The lime gradually combines with the water of the alcohol (it slakes), and the latter is procured anhydrous by distilling it off at a moderate heat. The best method of distilling in this case is over the water-bath (Fig. 83). *Anhydrous* alcohol is also called *absolute alcohol.* In this experiment, the vessels used must be previously rinsed out, not with water, but with strong alcohol, because the moisture adhering to the vessel would again impart water to the anhydrous alcohol.

499. *Properties of Alcohol.* — Alcohol has a burning taste, and a penetrating, agreeable odor. Strong alcohol, especially absolute alcohol, acts as a poison when swallowed; but when diluted, it is, as is well known, stimulating and intoxicating.

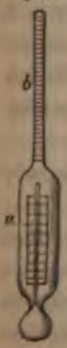
Strong alcohol has never been *frozen*, even at a cold of —100° C.; it is therefore excellently adapted for the making of thermometers by which great degrees of cold are to be measured. For this reason it is likewise serviceable in the illuminating-gas apparatus, for preventing in winter the freezing of the water which settles in the gas-pipes, and the consequent obstruction of the pipes. The illuminating gas, on leaving the gasometers, is first made to pass through alcohol before it is conducted farther, whereby the steam is not only withdrawn from the gas, but so much vapor of alcohol is also added to it, that the liquid now condensing in the pipes does not freeze at the temperature of our winters.

If common alcohol is placed in an open vessel, the alcohol *evaporates* more rapidly than the water contained in it. Strong alcohol may also attract water from the air. Thus is explained why all spirituous liquids must, when in unclosed vessels, lose strength, and become richer in water. The young chemist is frequently reminded of this fact in the case of the spirit-lamp; it will not burn when it has remained exposed to the air for some time unprotected. Why not? The spirit has passed away through the wick, the phlegm remaining behind.

The *boiling* and *evaporation* of alcohol have already been treated of at §§ 493 and 494, and the *combustion* of it in § 121. Alcohol contains so little carbon, that no soot is separated during its combustion; hence, also, the alcohol flame emits but a feeble light. The strength best adapted for spirit used in burning is that from 75° to 80° Tralles; if it is weaker, all the water will not evaporate during the combustion, and phlegm remains behind.

500. Alcohol may be mixed with *water* in every proportion, and it becomes specifically heavier the more water it contains; therefore, its specific gravity is a very simple, and at the same time a sure, test for the greater or less strength of alcohol. This is most conveniently ascertained by the areometer (*alcoholometer*). Absolute alcohol has a specific gravity of 0.792; that is, a vessel capable of containing just 1,000 grains of water is entirely filled by 792 grains of absolute alcohol; it is accordingly about one fifth lighter than water. In this alcohol, the alcoholometer sinks to the topmost point of the scale, to 100°, while in pure water it sinks to the lowest degree only of the scale, which is marked 0° (§ 16). The scales most in use are those of *Tralles* and *Richter*, which deviate very widely from each other, since *Tralles* made the mixtures of alcohol and water from which he determined the degrees by *measure* or *volume*, while *Richter* made them by *weight*. The former, for instance, called that alcohol which consisted of one measure of alcohol and one measure of water, *fifty degrees;* but the latter gave this number to a mixture consisting of one pound of alcohol and one pound of water. There must, of course, be more alcohol in the latter than in the former mixture, because one pound of alcohol occupies a greater volume than one pound of water; and thus is explained why one and the same alcohol shows more degrees on Tralles's alcoholometer, and consequently appears stronger than by Richter's.

Fig. 197.



If you mix 50 measures of alcohol and 50 measures of water, you do not obtain 100 measures, but only about 97; thus a *condensation* takes place, as in the mixing of sulphuric acid with water (§ 173). This explains the heating which always takes place when water and alcohol are mixed together. The knowledge of this fact is of economical importance for those merchants who now frequently prepare brandy by diluting strong spirit with water, since this liquid is commonly sold by measure.

501. Alcohol, like water, is a *solvent* for many substances, and, indeed, it not only dissolves many substances which are also soluble in water, such as tannin, sugar, &c., but many others, which are insoluble or nearly insoluble in water, such as resins, volatile oils, &c.

Experiment. — Pour into a flask, containing one dram of bruised *gall-nuts*, an ounce of water, and into another flask, containing the same quantity of gall-nuts, an ounce of alcohol; fasten over both flasks a piece of moistened bladder, in which some holes have been pierced with a needle, and set them aside for some days in a warm place. We obtain in both cases dark-colored, very astringent-tasting liquids (*infusions and tinctures*), which are to be clarified by filtration. They both hold in solution a peculiar principle of gall-nuts, called *tannin* or *tannic acid.* The watery infusion will decompose after a time, with the formation of vegetable mould; but not so the spirituous tincture, because alcohol has the power of preventing the commencement of putrefaction.

Experiment. — Prepare in the way just described an infusion from one dram of powdered *cinnamon* and water. A slightly colored liquid is obtained, and this, if evaporated on a warm stove, leaves behind an almost tasteless gum, which easily dissolves again in water. Now pour some alcohol upon the cinnamon that remains, and let them digest for several days; we shall obtain a dark-brown, fiery, spicy, and astringent-tasted liquid (*tincture of cinnamon*). If some of this tincture is evaporated to dryness, a brown, glistening mass (*resin*) remains behind, which may be redissolved in alcohol, but not in water. Besides several other substances, the water has accordingly dissolved principally gum, the alcohol principally resin (and volatile oil) from the cinnamon.

These examples are sufficient to show in how many ways alcohol may be employed as a means of solution and preservation. The principal solutions effected by it are, —

a.) The *tinctures* of pharmacy, alcoholic extracts of medicinal plants, roots, barks, &c.

b.) The *lac varnishes*, solutions of resin in alcohol.

c.) The so-called *perfumed waters*, eau de Cologne, solutions of volatile oils in alcohol, &c.

d.) The *liqueurs* and *cordials*, solutions of volatile oils (oil of cumin, oil of peppermint, &c.) sweetened with sugar, or of bitter and aromatic substances (sweet-flag, cloves, orange-peel, &c.), in alcohol.

Two of the various changes which alcohol may undergo are specially important, namely. its conversion into *ether* and *vinegar*.

VII. CONVERSION OF ALCOHOL INTO ETHER.

502. *Elayle, or Olefiant Gas.* — *Experiment.* — Mix very gradually, and with constant stirring, two ounces of common sulphuric acid with half an ounce of strong alcohol (§ 84); the heating which ensues on the union of these two fluids is still greater than that which takes

place on mixing together sulphuric acid and water. When the mixture is cold, pour it into a flask, and heat it in a sand-bath (see Fig. 84), at first cautiously, that it may not rise over, and afterwards somewhat more strongly; a kind of gas is evolved, which is to be collected, as has been described, in flasks immersed in cold water. Inflame the gas contained in one of the flasks, and immediately pour in water; it burns with a highly luminous flame; it is *illuminating gas* ($C_4 H_4$), which is formed from the alcohol. The alcohol is resolved into *illuminating gas* and *water*, which latter combines with the sulphuric acid remaining behind.

Fig. 198.

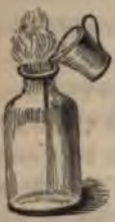
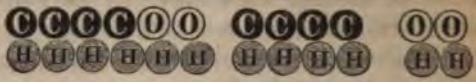


Fig. 199.



There is formed from alcohol, illuminating gas and 2 water.

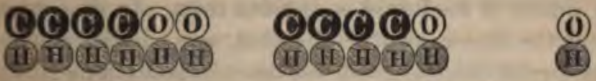
There are likewise formed at the same time sulphurous and carbonic acids, the former of which may easily be recognized by the smell; they are generated by the carbon of a portion of the alcohol decomposing a portion of sulphuric acid, and abstracting from the latter its oxygen. In order to purify the illuminating gas from these two volatile acids, it has only to be conducted through milk of lime before it is collected.

The illuminating gas thus obtained has received the name of *elayle*, or *olefiant* gas, because it condenses with the chlorine, forming an ethereal liquid, which, like oil, is insoluble in water.

503. *Sulphuric Ether.*—*Experiment.*—Mix one ounce of strong alcohol with one ounce of common sulphuric acid, but now without cooling the vessel by cold

water, because by the heating of the mixture the desired chemical change is promoted. That such a change has really taken place is known by the peculiar smell, different from that of alcohol, and by the altered (brownish) color of the liquid. The change which a portion of the alcohol has hereby experienced is as follows: —

Fig. 200.



There is formed from alcohol, ether (oxide of ethyle), and 1 water.

While in the former experiment, by an excess of sulphuric acid, two atoms of oxygen and two atoms of hydrogen were separated from the alcohol, in the latter case the alcohol loses only half as much of these two elements, namely, one atom of each, which two combine to form water. From the alcohol ($C_4 H_6 O_2$) there is formed a new body ($C_4 H_5 O$) which has received the name *oxide of ethyle* (Ae O), because it is able, like a base, to combine with acids. In the present case the oxide of ethyle meets with free sulphuric acid, with which it combines, forming *bisulphate of oxide of ethyle* ($Ae O, 2 S O_3 + 4 H O$). This compound, which is contained in the *elixir acidum Halleri* and in the *mistura sulphurico-acida,*[*] is more simply designated by the name of *sulphuric ether.*

504. *Ether.* — If the liquid of the preceding experiment, consisting of sulphuric ether, is heated, it resolves itself into oxide of ethyle (ether), water, and sulphuric acid.

Experiment. — Put the mixture prepared from alcohol and sulphuric acid into a flask connected with a glass tube and a receiver (see Fig. 106), close the opening remaining between the neck of the receiver and the glass tube by binding round it a piece of moistened bladder, in which some fine holes are pierced, and heat the flask *carefully* in a sand-bath till the contents of it assume a bubbling motion. Maintain the boiling of the liquid till about half, or at most three quarters, of an ounce of the liquid is distilled over. In this experiment the liquor, as it is distilled, must be subjected to a powerful refrigeration, because it is extremely volatile; it is therefore advisable *to perform the experiment in winter*, and to surround the receiver with snow. Care must also be taken not to bring any burning substance too near the vapors or the liquid which pass over, as they are both *exceedingly inflammable.* The distilled, colorless liquid possesses a penetrating, pleasant smell; it is called *crude ether.*

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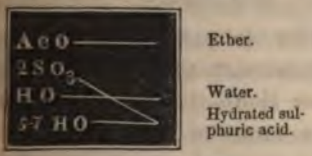
[*] Preparations occurring in some European pharmacopœias.

In order to purify it, shake it up in a small vessel with half an ounce of water, and one dram of potassa lye; close the vial, and let it remain standing for an hour with the bottom upwards. Crude ether contains a mixture of water, alcohol, and frequently also, when the distillation is continued too long, some sulphurous acid; these substances combine with the water and the potassa added, and form with them the heavier liquid layer, which settles at the bottom of the vial. The very thin and mobile liquid floating above is *ether*, which separates, because it comports itself towards water in the same manner as oil does, and is dissolved by it only in very small quantity. If you now loosen the stopper of the inverted vial, the aqueous liquid will run out, while the ether remains behind. If the latter is required entirely pure, it must be again distilled or rectified.

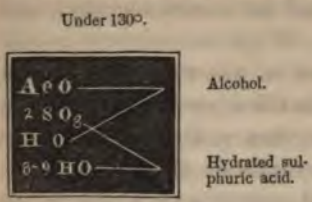
The most profitable way of preparing ether on a large scale is the following. Nine pounds of sulphuric acid and five pounds of alcohol are mixed together, and heated to the boiling point. While the mixture is still boiling, just so much alcohol is allowed gradually to drop in, as there is ether distilled over. One single pound of sulphuric acid is then sufficient gradually to convert into ether thirty pounds of alcohol, at ninety per cent., or an unlimited quantity of absolute alcohol.

505. *Explanation of the Formation of Ether.* — Alcohol is distinguished from ether merely by this, that it contains one atom of hydrogen and one atom of oxygen, consequently one atom of water, more than the latter. Accordingly, the production of ether may thus be explained in the simplest manner: sulphuric acid, on account of its strong affinity for water, abstracts from the alcohol one atom of water, and thus the alcohol is converted into ether. But the process is somewhat more complex, because there is an intermediate station — the bisulphate of oxide of ethyle — on the way between the alcohol and the ether. This complex compound, having the character of a salt, acts very differently according as it is heated in a concentrated or in a diluted condition. When diluted with six, or, at most, with eight atoms of water, this compound boils at from 130° to 140° C., and is thereby resolved into ether, water, and hydrated sulphuric acid; the two former volatilize without combining chemically with each other, and the latter remains behind. When the bisulphate of the oxide of ethyle is diluted with from nine *to ten atoms* of water, it boils even at a

At 130° to 140°.



lower temperature than 130° C., and is thereby resolved into alcohol and hydrated sulphuric acid. Here, too, ether and water are first separated, but both, when in a nascent state, combine chemically with each other, forming alcohol. This is the reason why, in the last-mentioned method of preparing ether, the sulphuric acid becomes ineffectual after it has transformed thirty times its own weight of alcohol at ninety per cent. into ether; it has then become so diluted by the water which it has abstracted from the hydrated alcohol, that nearly nine atoms of water have combined with two atoms of sulphuric acid. It has already been shown, in the first part of this work, by several experiments, how other bodies also, at different temperatures, evince sometimes a stronger, sometimes a weaker affinity for water, or, indeed, none at all for it.



506. *Experiments with Ether.*

a.) Pour some drops of ether upon the hand; it will evaporate in a few moments, imparting to the hand a perceptible feeling of coldness (§ 40). Ether is so *very volatile* that it boils when in summer it is put in the sun (at 35° C.); therefore it must always be kept in tightly closed bottles, and in cool places.

b.) Dip one piece of wood into ether, another into alcohol, and hold both to the flame of a candle; the ether *burns* with far greater briskness, and also with a much more luminous and a somewhat fuliginous flame. Its stronger illuminating power is simply ex*plained* by its containing a larger amount of carbon.

The process in burning is the same as with alcohol; the ether being also converted into carbonic acid and water.

c.) If you pour some drops of ether into a tumbler, and after some minutes, when the ether is converted into vapor, apply to it a burning taper, a sudden ignition ensues, accompanied by an explosive noise. The vapor of ether forms, like hydrogen or marsh gas, when mixed with atmospheric air, a kind of *explosive gas*, and several violent explosions have been occasioned by carrying lighted candles or lamps into those places where, owing to the breaking of a bottle filled with ether, its vapor has become diffused in the air.

d.) Ether may be mixed with alcohol in any proportion whatever. When mixed with three parts of alcohol, it is much used as a stimulating and restorative medicine, under the name of *Hoffmann's anodyne liquor*.

e.) Put a piece of *tallow*, or a few drops of olive oil, into a test-tube with some ether; both will entirely dissolve in it. But they are not soluble in alcohol or water. Therefore ether may be advantageously employed for dissolving and separating such substances as will dissolve in it, but not in other liquids. Besides fat, many of the resins, and the so-called gum elastic (caoutchouc), are soluble in ether.

Ether is also very generally called *sulphuric ether;* but this appellation is incorrect, since pure ether neither contains sulphuric acid, nor has any sulphur in its composition.

507. *Combinations of Ether with Acids.*

It has already been stated, that ether, though it does not give a basic reaction, yet comports itself as a base, that is, combines with acids. These combinations, however, cannot be directly produced by the mixture of ether with acids. Ether combines with acids at the moment of formation only, or when it is liberated from some other combination; but after it has once been set free, it no longer shows any inclination to combine with acids. These combinations may be called salts of ether, or salts of oxide of ethyle, just as the terms salts of potassa and salts of potassium are used, but they are generally spoken of as *kinds of ether*. Most of them are liquid, and have a volatile, cooling taste. They are commonly prepared by distilling the different acids with alcohol, and often in the presence of sulphuric acid. Those only which are best known will be here alluded to.

Acetate of Oxide of Ethyle, or *Acetic Ether* ($Ae\,O, \bar{A}$), is a very volatile liquid, having an agreeable odor, and is employed in medicine.

Nitrite of Oxide of Ethyle, or *Nitrous Ether* ($Ae\,O, N\,O_3$), has an agreeable odor, like that of fruit, and is contained, diluted with alcohol, in the *spir. nitr. æth.* (sweet spirits of nitre) of the apothecaries, which is known as a medicine.

Chloride of Ethyle, or *Muriatic Ether* ($Ae\,Cl$), forms a constituent of the spirit of muriatic ether.

Œnanthate of Oxide of Ethyle, or *Œnanthic Ether* ($Ae\,O, \overline{Oe}$), is contained in wine, and is the cause of the so-called bouquet of certain sorts of wine.

Butyrate of Oxide of Ethyle, or *Butyric Ether*, now occurs in commerce under the name of rum-ether, or essence of rum, and is used for imparting to alcohol an odor similar to that of rum.

508. *Organic Radicals.*

Formerly organic substances were considered as immediate combinations of carbon, hydrogen, oxygen, nitrogen, &c.; accordingly they were divided into ternary compounds (having three elements), quaternary (having four elements), &c. But in modern times the hypothesis has been adopted, that a simple manner of combination may exist in organic substances analogous to that of the inorganic compounds; namely, that a simple group of atoms, as of carbon and hydrogen, may comport itself in the same way as an element or a radical; the group $C_2 N$ (cyanogen), for instance, comports itself as such. This supposition has already been most beautifully confirmed in many cases, and since alcohol and ether, and their metamorphoses, are peculiarly adapted for illustrating this new mode of considering the subject, we will cite them as examples. In these combinations we consider a group of four atoms of carbon and five atoms of hydrogen ($C_4 H_5$) as the elementary substance, as the radical, and call it *ethyle* (Ae). Accordingly, we now regard ether ($C_4 H_5 O$) as oxide of ethyle ($Ae + O$); alcohol ($C_4 H_6 O_2$) as hydrated oxide of ethyle ($Ae\,O + H\,O$); sulphuric ether as bisulphate of oxide of ethyle ($Ae\,O, 2\,S\,O_3 + 4\,H\,O$); acetic ether as acetate of oxide of ethyle ($Ae\,O, \bar{A}$); muriatic ether as chloride of ethyle ($Ae\,Cl$), &c.

It will be readily perceived from this grouping, that the organic compounds show a surprising resemblance to the inorganic, and may be very well compared with them; the ethyle series, for instance, with the potassium series, in the following manner:—

Potassium	corresponds	to	ethyle,
Potassa	"	"	oxide of ethyle (ether),
Hydrate of potassa	"	"	hydrated oxide of ethyle (alcohol),
Bisulphate of potassa	"	"	bisulphate of oxide of ethyle,
Acetate of potassa	"	"	acetate of oxide of ethyle (acetic ether),
Chloride of potassium	"	"	chloride of ethyle, &c.

The radicals of this kind, among which may be reckoned, also, cyanogen and ammonium, are termed *compound* or *organic radicals.* Ether belongs to the division of radicals *forming bases.*

VIII. CONVERSION OF ALCOHOL INTO VINEGAR.

509. *Experiment.* — Mix in a glass vessel half an ounce of brandy with three ounces of spring-water, and put in the liquid a slice of leavened rye bread, or black bread (*Schwartzbrod*), which has been previously soaked in strong vinegar, or instead of it a little leaven; cover the vessel with a piece of perforated pasteboard, and put it in a place where the temperature is between 30° and 40° C.; the spirituous liquor will, after some weeks, be converted into vinegar. This conversion does not take place in a closed vessel, as the oxygen of the air is indispensable to the process; a great quantity of oxygen is consumed, since the *formation of vinegar consists in an oxidation of the alcohol by the oxygen of the air.* Neither is any vinegar formed if you do not add the bread or the leaven. As the solution of sugar does not of itself pass over into alcohol, neither does the alcohol of itself pass over into vinegar. But as an easily resolvable body (ferment, yeast, &c.) disposes sugar to enter into decomposition simultaneously with itself, so also acid bodies, that may be easily decomposed, such as black bread, leaven, vinegar, &c., are able to bring the alcohol into that state in which it absorbs oxygen. The mode of action of these substances, which are called vinegar ferments, resembles that of the

nitric oxide in the sulphur-chambers; they are, like the latter, *the transferrers*, that is, they attract the oxygen from the air, and give it up again to the diluted alcohol.

In the same manner with pure diluted alcohol, all other *alcoholic liquids*, as beer, wine, cider, &c., may, by receiving oxygen, be converted into vinegar, and it is well known that vinegar is frequently prepared from them. If, as is ordinarily the case, they contain gluten or lees in solution, then these substances replace the vinegar ferment, and the acidification ensues spontaneously, when the liquid is exposed in loosely covered vessels to a temperature of from 30° to 40° C. This acidification most readily occurs immediately after a spirituous fermentation, which has taken place at too high a temperature; for this reason, in the hot months of summer, the brewers and brandy-distillers find difficulty in keeping their fermenting wort and mash from turning sour, which can only be prevented by rapid refrigeration.

Liquids, also, containing *starch* and *sugar*, may pass over into vinegar, but only after these have been previously converted by fermentation into alcohol. This explains why the farmer obtains vinegar, when, having poured water upon the peels and refuse of fruit, he sets them aside near the stove; why boiled food, preserved fruits, &c., become acid after a time. The spirituous fermentation, which first takes place, is always followed by an effervescence or fermentation in these cases, because the carbonic acid, formed from the sugar at the same time with the alcohol, escapes. From this is derived the term *vinegar fermentation*, by which, in earlier times, the process of the formation of vinegar was designated, this effervescence being regarded as an essential phenomenon in the generation of vinegar.

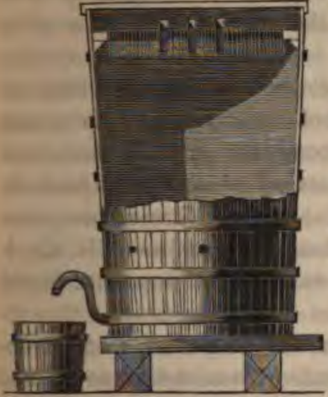
But it is now known that no evolution of gas takes place during the conversion of alcohol into vinegar.

510. *Experiment.* — Fill two tumblers loosely with the stalks of grapes, and fill one entirely and the other only half full with wine, beer, or a mixture consisting of one part of brandy, one part of beer, and six parts of water. Put both vessels in a warm place, and once or twice every day pour the mixture from one vessel into the other, so that each may be alternately full and only half full of the liquid. The alcohol contained in the brandy will, in this manner, be much more rapidly oxidized into vinegar, because the liquid adhering to the grape-stalks is, in this state of fine division, surrounded by air, and thus has a far better opportunity of attracting oxygen from the latter. The effervescence taking place at the commencement was owing to the sugar contained in the beer and the grape-stalks, and which was first converted into alcohol and carbonic acid. The alcohol thus formed was likewise afterwards changed into vinegar, and this is the reason why the vinegar thus produced is more acid, that is, richer in acetic acid, than that obtained by the former experiment.

511. *Quick Method of making Vinegar.* — The transition of alcohol into acetic acid takes place yet more rapidly by subdividing the alcohol still further, or by exposing a still greater surface of the liquid to the air than in the way just described. This is effected in the following manner.

A tub four or five yards high is filled with shavings of beech-wood, and is furnished with a perforated shelf, which is placed somewhat below the upper opening. Through each of the small holes a straw or a piece of packthread is passed, prevented from falling

Fig. 201.



through by a knot at the upper end. By this means an extreme division of the alcohol is effected, as when it is poured in at the top, it only trickles slowly down through the holes by means of the straw or packthread, and then diffuses itself over the shavings, forming a very thin liquid layer, which presents to the air a surface many thousand times more extensive than was produced by any former method. Several large holes are bored round the lower part of the tub, and likewise in the perforated shelf; glass tubes are fitted into the holes made in the latter, in such a manner that the liquid, when poured into the top, may not run off through them. A free circulation of air is hereby produced, the cooler air enters by the openings in the tub, gives up its oxygen to the alcohol diffused over the shavings, and in consequence of this oxidation, or slow combustion, so much heat is evolved in the interior of the tub, that the temperature rises to 40° C. The air, hereby becoming warmer, and consequently lighter, passes out of the tub through the glass tubes in the shelf, and from an eighth to a fourth poorer in oxygen than when it entered. Strong vinegar is used as a ferment in this process, the tub and shavings having previously been moistened with it, and a certain quantity being also added to the mixture of brandy which is to be converted into vinegar. In such a tub (*vinegar-generator*), heated brandy, beer, wine, &c. may be converted into vinegar in a few hours, by being passed through the cask three or four times; hence this is called *the quick method of making vinegar.*

512. *Explanation of the Process of forming Vinegar.* — In order to convert alcohol into vinegar, four atoms of oxygen must enter into combination with one atom of alcohol. From one atom of alcohol and four atoms of oxygen, $= C_4 H_6 O_2 + 4 O$, are formed one atom of acetic acid and three atoms of water, $= C_4 H_3 O_3 + 3 H O$. The alcohol is accordingly oxidized into acetic acid and water.

This process may be regarded as a slow and imperfect combustion, and we shall here also find confirmed what was stated of the combustion of wood in the air (§ 120), and of the combustion of sugar by nitric acid (§ 196); namely, that the easily combustible and easily oxidized hydrogen combines with the oxygen before the difficultly combustible carbon does. Here, as is obvious, none of the carbon of the alcohol is consumed, but one half of its hydrogen is consumed or oxidized by the oxygen of the air, one atom of oxygen, moreover, being taken from the air.

Aldehyde. — We have thus far considered only the starting point (alcohol) and the extreme point (acetic acid) of the process of the formation of vinegar; but half way between these two there is a peculiar compound, which may be regarded as half-converted alcohol, or half-made vinegar. It is formed from the alcohol when two atoms of oxygen enter into combination with it, thereby converting two atoms of its hydrogen into water. The name *aldehyde* (that is, *al-* alcohol, *de-* from which, *hyd-* hydrogen is taken) has been given to it.

From alcohol, $= C_4 H_6 O_2$ and $2 O$,
is formed aldehyde, $= C_4 H_4 O_2$ and $2 H O$.

This compound is always produced in the first period of the formation of vinegar, and occasions the peculiar suffocating smell often perceived in vinegar-chambers. *Aldehyde* very greedily attracts two more atoms of oxygen from the air, and is thereby converted into hydrated acetic acid ($H O, C_4 H_3 O_3$). This occurs in the second period of the formation of vinegar, when an acid odor prevails in the vinegar-chambers.

Aldehyde may be very easily produced, and it may be readily recognized by its characteristic odor, when, as was directed in § 114, a glowing platinum wire is held in alcohol vapor, or yet more easily, by pressing down an alcohol flame by a wire net. In both cases it is formed because the temperature is not high enough to effect a complete combustion of the alcohol vapor. A portion of the latter then takes up only two atoms of oxygen from the air, and there is produced aldehyde vapor, and, together with this, some acetic acid and other gaseous products.

After this statement of the process of the formation of vinegar, it will no longer appear strange that aldehyde and acetic acid are formed in all cases when alcohol unites with bodies which are rich in oxygen, and which readily part with it, as, for instance, chromic acid, nitric acid, black oxide of manganese, sulphuric acid, &c.

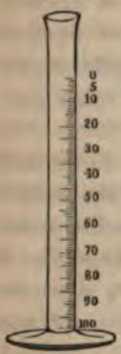
It may now also be easily explained how vinegar is produced from wood by dry distillation. Wood consists of $C_6 H_5 O_5$; acetic acid of $C_4 H_3 O_3$, or, if multiplied by $1\frac{1}{2}$, of $C_6 H_{4\frac{1}{2}} O_{4\frac{1}{2}}$. Consequently, it is only necessary to abstract a little hydrogen and oxygen from *the wood, in order to* transfer it into acetic acid.

513. *Acetyle.* — Aldehyde and acetic acid may, like ether and alcohol, be regarded as combinations of an organic radical. This radical is called *acetyle* (Ac), and it is assumed to be composed of four atoms of carbon and three atoms of hydrogen ($C_4\ H_3$). Accordingly, aldehyde ($C_4\ H_4\ O_2$) is the same as hydrated oxide of acetyle ($Ac + O + H\ O$); acetic acid ($C_4\ H_3\ O_3$) is the same as oxide of acetyle ($Ac + 3\ O$).

Acetyle belongs to the class of *radicals forming acids.*

514. *Properties of Vinegar.* — Vinegar is an acetic acid diluted with much water, and frequently mixed also with foreign substances, which it obtains from the malt, fruit, wine, &c., from which it is prepared. The esteemed yellow or brownish color is often imparted to it artificially by burnt sugar, or extract of chicory. The vinegar which occurs in commerce under the name of wood-spirit contains in every hundred measures from eight to twelve measures of acetic acid, wine-vinegar from six to eight, and common table vinegar only from two to five; the rest is water. In order to ascertain the strength of vinegar, we adopt a course similar to that used in testing carbonate of potassa (§ 202); that is, we examine how much of some base (ammonia is the best) a fixed quantity of it is able to neutralize. Glass cylindrical jars, constructed for this purpose, and divided into degrees, are called *acetometers.*

Fig. 202.



If vinegar is allowed to remain for some time exposed to the air, it begins to decompose (to putrefy), and so much the more readily the weaker it is. This is indicated sometimes by a white film (mould), sometimes by the separation of gelatinous matter (*vinegar mother*), sometimes by the generation of infusoria, which can often be distinguished by the naked eye when a glass of vinegar is held towards the sun (*vinegar eels*). Further decomposition may be arrested for a time by boiling the vinegar.

Vinegar is somewhat *less volatile* than water. When it is distilled, first a weaker, and finally a stronger, colorless vinegar passes over (*distilled vinegar*), and the foreign non-volatile mixtures remain behind.

When vinegar is exposed to the *cold*, the water contained in it is frozen before the acetic acid is; hence, weak vinegar may be made stronger by partial freezing. Wine, when exposed to the cold, acts in the same manner.

To impart to vinegar a more pungent or more acid taste, such substances as Spanish pepper, pellitory root, and indeed sulphuric acid, are sometimes added to it. The latter adulteration may readily be detected in the following manner.

Experiment. — Fill a jar half full of water, and place upon it a cup containing the vinegar to be tested, together with some grape-sugar; then let the jar remain on a hot stove till the vinegar has evaporated. If the residuum is of a black color, then the vinegar contains sulphuric acid. When heated over hot water, the vinegar only is volatilized, while the sulphuric acid, if any is present, remains behind, and finally, when all the aqueous particles have vanished, attains such a strength, that it decomposes the sugar and chars it.

Fig. 203.

CONVERSION OF SUGAR INTO LACTIC AND BUTYRIC ACIDS.

515. If an open vessel, containing some expressed juice of the beet, is put in a warm place, where it will be heated to between 30° and 40° C., the beet-juice will enter into fermentation, in the same manner as in § 482; but when the fermentation is finished, notwithstanding that all the sugar has disappeared, we do not find any alcohol in the fermented liquid, but a peculiar acid (*lactic acid*), and a mucilaginous gummy substance. This process of decomposition has been called *mucilaginous fermentation;* it very remarkably illustrates the extremely different kinds of decomposition of one and the same organic substance, according to the temperature at which the decomposition takes place. At a temperature of from 10° to 20° C., the beet-juice entered into spirituous fermentation, and its sugar was resolved into carbonic acid and alcohol; at a higher temperature it likewise fermented, but in this case the sugar is converted into carbonic acid, lactic acid, gum, and some other products.

The sugar contained in many vegetable substances likewise undergoes a similar change, when these are mixed with salt, and kept for some time in a compressed state. The acid taste which we perceive in pickled cabbage, beans, gherkins, &c., is owing principally to *lactic acid*, which is formed in these substances in a way not yet thoroughly investigated.

But beside this acid, we frequently find in the above-mentioned pickles another, called *butyric acid*, which imparts to them their peculiar odor. This acid, it *seems*, may also be produced by the metamorphosis of vegetable mucus, for it is always generated when vegetable mucilaginous substances — for instance, althæa-root, quince-cores, linseed, &c. — are allowed to remain for some time in water.

FORMATION OF ALCOHOL, ACETIC ACID, AND LACTIC ACID, ON THE BAKING OF BREAD.

516. *Meal.* — The seeds of the various kinds of grain which we use in the preparation of meal and bread contain, as principal constituents, *starch* and *gluten*, and also a little sugar. On grinding the grain, the husks and the parts contiguous to them, which are rich in oily matter (nitrogen and phosphate of lime), separate, constituting the *bran*, and there is left from the inner whiter mass, called the albuminous substance, the *meal.* The gluten is tougher, and more difficult to grind, than the starch; this explains why the finer *white meal*, obtained by repeated sifting (bolting), is *richer in starch*, while the coarser and *darker meal* is *richer in gluten.* The nutritive property of meal is to be ascribed to the azotized gluten; unbolted meal, and bread made of it, are accordingly more nutritive than white meal and white bread, but at the same time less digestible (soluble).

Experiment. — Mix some flour with lukewarm water to a thick paste, cover it with a board, and let it remain for eight or ten days in a warm place. The paste is gradually altered, and two distinct periods may be observed during the change. In the first place, on the second or fourth day bubbles of air are evolved from it, having an acid, unpleasant smell, and the dough now possesses the capacity of converting sugar into *lactic acid*, as may be readily perceived by adding a little of it to some sugared water, and letting it stand in a warm place. *After six or eight* days the dough acquires a pleasant smell, and it now acts, when added to a solution of sugar, like yeast; that is, it effects a decomposition of the sugar into *alcohol and carbonic acid.* If the dough is allowed to stand yet longer, it again acquires an acid taste, but which now proceeds from the *acetic acid* into which the alcohol previously generated gradually passes over (*leaven*). In this state it also excites a spirituous fermentation in sugared water; but this spirituous fermentation immediately passes over into the acid, into *vinegar formation.* It is obvious, from what has previously been stated, that the different actions of the flour, when in a state of decomposition, upon the sugar, depend upon the albuminous matter, the gluten, contained in the flour; consequently, we might call the slightly altered gluten a lactic acid ferment, that which is more altered an alcohol ferment, and that which is still further altered a vinegar ferment.

517. *Bread.* — What thus takes place slowly proceeds rapidly in the making of bread, since a ferment is purposely added to the flour, which has been stirred up with water.

In the making of white bread, the surface yeast of beer is used as a ferment; this, as is known, is the most powerful alcohol ferment. The sugar contained in the meal is thereby resolved into alcohol and carbonic acid, which struggle to escape, whereby the tough mass of dough is disintegrated, and rendered light and porous (*rising of the dough*). These substances, together with about half the water employed, volatilize by the rapid heating in an oven, having a temperature of from 100° to 180° C., and the cellular partitions of the baked bread attain such a solidity, that they retain their form and place even after cooling. But if the heat of the oven is not sufficient, or the dough is too watery, then the partitions harden too slowly, and, on the escape of the carbonic acid, collapse, or run into each other (*slack baking*). This happens most frequently with dark bread, since, in consequence of its amount of gluten, it retains the water more obstinately, and accordingly dries and hardens more slowly, than white bread, in which the starch is more abundant.

Leaven is commonly used as a ferment in the preparation of black bread. There is formed, during the process, besides alcohol and carbonic acid, a little acetic and lactic acids (perhaps also some butyric acid), which communicate to the bread an acid taste. From three pounds of flour we obtain about four pounds of bread; consequently, a quarter of the bread consists of fixed water. The light, porous bread dissolves easily in the stomach; we say that it is easily digestible, and that the compact heavy bread is difficultly digestible.

518. It is known (§458) that starch is converted, by roasting, into *gum* (dextrine); a part of the starch undergoes, also, this change in the oven, particularly on the surface of the baked bread, which receives the strongest heat from the roof of the oven. If the crust of the hot bread is rubbed over with water, and the bread is then replaced for a few minutes in the oven, some of the dextrine is dissolved, and forms, after the evaporation, the lustrous coating which we see on loaves of bread, and rolls.

519. Carbonic acid, as applied to the rising of bread, may be more or less advantageously generated in other ways than by the fermentation of sugar; indeed, quite other substances may be used for the purpose, such as those which become aeriform on the application of heat.

Experiment. — Mix intimately together two grains of finely pulverized *bicarbonate of soda*, and a dram and a half of flour, and knead the mixture into a dough with one dram of water, to which four drops of common muriatic acid have previously been added. Let the dough remain for some time in a warm place, and then bake it on the hot flue of a stove, or in a spoon over an alcohol lamp. A porous mass of bread is obtained, because the carbonic acid of the soda salt is expelled by the muriatic acid, and raises the dough while it is yet soft. The common salt which is formed remains behind in the bread, and imparts to it a saline taste. This method has been introduced in many places for making bread, cake, &c. on a large scale.

Experiment.—Rub a dram and a half of flour with some grains of *carbonate of ammonia*, and then knead it with a dram of lukewarm water into a dough, and treat it as in the last experiment. In this case, also, the mass will become light and porous after the rising and baking, because the carbonate of ammonia (salt of hartshorn) is rendered aeriform by the heat, and during its escape the particles of the dough are forced asunder. In this way the bakers usually prepare their light and spongy cakes, as, for instance, spice-cakes, &c. *Alcohol* and *rum*, which are sometimes kneaded with dough to promote the rising, act in a similar way.

RETROSPECT OF THE CHANGES OF SUGAR AND ALCOHOL.

1. *Sugar* is converted,—

a.) By the loss of oxygen and hydrogen, into water and brown substances rich in carbon.

b.) By the addition of oxygen, into saccharic acid, oxalic acid, and water, and finally into carbonic acid and water.

c.) By contact with azotized substances at a low temperature, into (rich in hydrogen) alcohol and (rich in oxygen) carbonic acid (spirituous fermentation).

d.) By contact with azotized bodies at a somewhat higher temperature, into lactic acid, mannite, and many other substances (mucilaginous fermentation).

2. By the changes mentioned under *c* and *d*, the azotized body is also simultaneously transformed into new combinations (yeast, ammoniacal salts, &c.).

3. The conversion of the sugar into alcohol and carbonic acid, and that of the azotized body into yeast, take place at a low temperature slowly (bottom fermentation), at a higher temperature rapidly (surface fermentation).

4. Hitherto alcohol has been prepared only by this method, namely, by the fermentation of sugar.

5. Starch is indeed used for the manufacture of alcohol, but it must always be previously converted into sugar.

6. *Alcohol* is converted, —

a.) By the loss of all its oxygen and some hydrogen, into elayle (olefiant gas) and water.

b.) By the loss of some oxygen and hydrogen, into oxide of ethyle (ether) and water; this oxide of ethyle can combine as a base with acids (compound ethers).

c.) By the addition of oxygen, into aldehyde and water, and by still more oxygen, into acetic and other acids. If we follow the process of oxidation, as it proceeds, we shall observe the following order of changes: —

From	alcohol and oxygen	are formed	aldehyde and water;
"	aldehyde and oxygen	" "	acetic acid;
"	acetic acid and oxygen	" "	formic acid and water;
"	formic acid and oxygen	" "	oxalic acid and water;
"	oxalic acid and oxygen	" "	carbonic acid.

7. The last products of this process of oxidation are consequently those into which the alcohol passes when it burns up, namely, carbonic acid and water.

8. Sugar belongs to the organic compounds rich in carbon, alcohol to those rich in hydrogen, acetic and the other acids to those rich in oxygen.

IX. FATS AND FAT OILS.

520. *Experiment.* — Break open an almond, and squeeze the white meat together by means of the finger-nail; small drops of fluid will be expressed, which are slippery to the touch, and render blotting-paper greasy and transparent. This liquid is called *oil of almonds.* If the almonds are first pounded, and then subjected in a cloth to strong pressure, we shall obtain more than one fourth of their weight in oil of almonds. A great many plants contain a similar oily juice, especially in their seeds, and from many of the latter oils are obtained by pounding and expressing. The term *fat oils* has been given to this kind of oils, because they are unctuous to the touch, and thick flowing. They occur, but less abundantly, in almost all plants, even in those where we should not expect to find any; for instance, in different grains, grasses, &c.

521. *Experiment.* — Boil some fat pork cut up into small pieces for some time in a little water, and while the soft mass is yet hot, strain it through a linen cloth; a fat oil will float on the surface, but it is fluid only at a temperature of about 30° C.; below this temperature it congeals into a solid, yet soft, white substance. This is also lubricating to the touch, and pro-

duces greasy spots on paper. Such kinds of fat, which, at the common temperature, have a *soft* unctuous consistency, are called *lard*, or, improperly, *fat;* and the cellular membrane and skin remaining in the cloth, and saturated with fat, are called *scraps.*

522. The suet of mutton, when treated in the same way, yields a fat which, when hot, is also fluid, like oil, but which, when cooled only to about 36° C., congeals, and then forms *tallow*, a still *harder* substance than lard. By boiling and roasting, we can melt out fat from all animal substances, especially from those of the domestic animals, in which we are able to produce a great quantity of fat by keeping them confined, and giving them a plentiful supply of food. The fats obtained by boiling with water are white, as thereby they do not become heated above 100° C.; while those obtained by roasting have a yellow or brown color (brown butter, gravies of roast meat, &c.), because in this case a portion of the fat becomes burnt by being subjected to a stronger heat, — to a heat, perhaps, even above 300° C. In a strict sense, animal fats belong to the last division of this work, but they agree in their properties so exactly with the vegetable fats, that the subject will be rendered more intelligible by considering them together under the same head.

The fats of vegetables are mostly liquid (fat oils), those of the carnivorous Mammalia and of birds are soft (lard), and those of the ruminating Mammalia hard (tallow).

PROPERTIES OF FATS.

523. *Experiment.* — Rub a little fat upon paper, and *place it upon a hot stove*; the grease-spot will not dis-

appear, however long the paper may be heated, since *the fats are not volatile.*

Fats not only spread with great ease on paper, but also on all other porous substances; as, for instance, on wood, leather, &c. Since the fats remain soft for a long time in the interior of these substances, we possess in them means for rendering flexible substances supple, and of maintaining them in this state. For this reason, leather harnesses and shoes are greased from time to time; and for the same reason, also, the leather-dresser impregnates his lamb-skins with fish oil in the fulling-mill, to give them greater softness and pliability when they are worked up into gloves, &c. That clay and loam have a great power of absorbing fat is obvious, as these substances are able to draw out again the grease that has been soaked into wood or paper. Thin substances acquire a greater transparency when their pores are filled with fat instead of air; common paper is rendered in this way so transparent, that it may be used for tracing and for transparencies.

524. The fats *float upon water;* they have accordingly a less specific weight than water. On account of this property, they may be used for excluding air from other bodies. A solution of green vitriol speedily attracts oxygen from the air, and deposits brown hydrated sesquioxide of iron (§ 285); but it remains unchanged when it is covered with an oily film. Freshly expressed lemon-juice soon moulds in the air; it does not mould under a covering of oil. Preserved fruits keep much longer when melted butter is poured over them.

Fats are *insoluble in water;* hence they may be used for protecting other bodies from being penetrated by water. By greasing with tallow or fat, we render our shoe-leather impervious to moisture; by oiling, we prevent the rusting of iron in the damp air; and by a coating of linseed oil, or linseed-oil varnish, we guard against the penetration of dampness into wood, sails, cordage, and their consequent rapid moulding and rotting. Lumber and timber saturated with oil remain, as has been shown by late experiments, unchanged in the moist earth, while common wood is frequently destroyed by putrefaction, in the course even of a few years.

525. *Emulsion.* — *Experiment.* — Shake some oil and water briskly together in a test-tube; the oil separates into small drops, and renders the water milky; but on quietly standing, it soon rises again to the surface. It is kept in suspension in the water much longer when some mucilaginous substances, such as gum or albumen, are contained in the water; as may be seen by triturating some oil with albumen, yolk of eggs, or a thick solution of gum Arabic, and afterwards gradually adding water. The milky fluid thus obtained is called an *emulsion* (*oleaginous emulsion*), and the oil in it will not separate from the water till after some days.

Experiment. — A second mode of preparing emulsions consists in bruising seed rich in oils, such as almonds, or rape-seed, in a mortar, and gradually adding water. In all these seeds mucilaginous and albuminous substances are present, which are dissolved by water, and effect a fine division of the oil.

We have a natural emulsion in the *milk* of milch animals. Cow's milk is turbid, because the butter floats about in it in small globules, invisible to the naked eye; these globules of fat are kept suspended in the water because a body similar to albumen — the caseine — is dissolved in the milk. On longer standing, the caseine becomes insoluble (it coagulates), and the lighter butter collects, as cream, upon the surface of the milk.

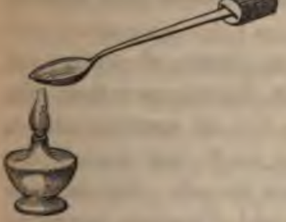
526. *Drying Oils and Unctuous Oils.* — *Experiment.* — Rub upon a copper coin a drop of linseed oil, upon another a drop of olive oil, and let them both remain for several days in a warm place; the linseed oil will dry up into a resinous *solid* mass, while the olive oil will remain *greasy.* All oils absorb oxygen from the air, and become thereby thicker, and also acquire a disagreeable smell and taste (rancid); but there is an essential difference between them, as many oils become perfectly hard and dry, while others, on the contrary, remain soft and sticky. Accordingly, oils are divided into two classes, into *drying* and *unctuous oils.* The former may also be called varnish oils, as they are particularly adapted for varnishing. The latter are called unctuous oils, because, when it is desired to prevent, by means of grease, the friction and heating of solid bodies, these oils remain soft and unctuous much longer than the drying oils.

527. By the absorption and condensation of oxygen taking place on the drying of oils, heat must be liberated, as in every condensation of an aeriform body to a liquid condition. Under some circumstances, as when freshly oiled or varnished substances, such as wool, linen, &c., are closely heaped together in large masses, this heat rises to such a degree, that *spontaneous combustion* occurs; therefore it is not prudent to lay such articles too closely upon each other, before they have become thoroughly dry.

CHANGES OF FAT BY HEAT.

528. *Experiment.* — Heat some linseed oil over an alcohol flame, and test the temperature of it occasionally by a thermometer. At first the heat rapidly rises to

Fig. 204.

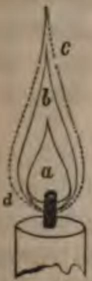


100° C., and remains for some time at that temperature, during which time the oil boils moderately; this behaviour is occasioned by all crude oil containing watery particles, which evaporate at 100° C. As soon as these have volatilized, the temperature is suddenly elevated even above 300° C., when the oil begins to boil for the second time, but emitting now a white smoke having a very disagreeable odor. This vapor consists of decomposed oil, principally of illuminating gas, and burns, when kindled, with a brisk flame; fats are accordingly *combustible*, but only at a temperature sufficiently high to effect their chemical decomposition.

Illuminating gas is frequently prepared on a large scale from oils, by causing them to drop upon a red-hot iron vessel, from which the gas generated (*oil gas*) is conducted by a pipe into a receiver (*gasometer*).

529. Every lamp, every candle, is an illuminating-gas apparatus on a small scale. But in this case the combustion takes place only with the aid of an easily combustible body, the wick. When a fresh candle is lighted, the cotton of the wick first inflames, and the heat thus produced is sufficient to melt the tallow in contact with the wick. The melted tallow now ascends by capillary attraction (§ 106), through channels formed by the fibres of the cotton lying beside each other, and in these channels it becomes heated by the flame to a temperature of above

Fig. 205.



300° C., and consequently is decomposed into illuminating gas. Whale oil, rapeseed oil, oil of colza, olive oil, tallow, and wax are most frequently used as *illuminating materials.*

530. *Experiment.* — Let some drops of water fall from a shaving, that has been dipped in water, into some oil burning in a spoon; the oil spatters about, because the heavier water sinks in it and is suddenly converted into vapor, which ejects the oil. Burning fat, such as varnish, lard, &c., should therefore never be quenched with water; but the quenching may be done easily and without danger, if the vessel is covered with a board or a piece of sheet-iron, thus excluding the air, which is requisite for continued combustion.

531. As in wood (§ 120), so also in fats, the hydrogen burns more briskly than the carbon, and this is the reason why the partly burnt oil remaining after the extinction is richer in carbon, and has a darker color. An *empyreumatic oil* of this kind is kept by the European apothecaries, under the name of *oil of bricks*, or *philosophic oil.* On yet further heating, the linseed oil becomes continually blacker, and at the same time thicker, so that it finally acquires a viscid consistency, (factitious birdlime), and when mixed with soot forms the basis of the important *printing-ink.*

COMPOSITION OF FATS.

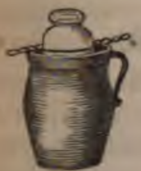
532. The similarity in the combustion of fats and wood indicates that they have a similar constitution. Indeed, both bodies possess the same constituents, namely, carbon, hydrogen, and oxygen; the difference depends only upon the quantity; the fats contain, namely, more *hydrogen* and less oxygen than wood. They accord-

ingly belong to one and the same category with alcohol and ether, — to that of the *organic bodies which are rich in water*.

533. *Stearine and Oleine.* — We cannot, however, regard fats, like woody fibre or alcohol, as homogeneous bodies, but as *mixtures of several more simple kinds of fat*, into which the fats, without being chemically decomposed, may be separated.

Experiment. — If, during the winter, you place a vessel containing lamp oil in the cold, part of it will congeal into a solid mass, like tallow, while the other part remains fluid ; the oil is accordingly separated by the cold into two fats, one solid and one fluid. The solid fat has received the name of *stearine*, the fluid that of *oleine*. By repeated cooling, the greater part of the stearine may be separated from the oil. The stearine obtained is pressed between blotting-paper as long as the paper absorbs any liquid oil (oleine).

Fig. 206.



Experiment.—Twist a wire round a wide-mouthed vial, in such a manner as to form two handles, by means of which the vial may be suspended in a jar, which is then half filled with water, and heated upon a tripod. Put into the vial one dram of tallow and enough strong alcohol — absolute alcohol is the best — to fill it three quarters full. When the contents of the vial boil, remove the lamp, and leave the vial in the water-bath, till the melted tallow has again settled at the bottom, and then pour the hot supernatant alcohol into a beaker-glass. Repeat the boiling three or four times, with fresh alcohol. Let the alcohol stand for some hours in cold water, covered over; afterwards filter the liquid from the granular powder that has separated, wash the powder several times with cold alcohol, and dry it in an airy place. This mass, which, when dry, is laminated and slightly lustrous, is the *stearine* of mutton-tallow; the *oleine* must be sought for in the filtered alcohol. It remains behind, in the form of a somewhat thick oil, when the alcohol is allowed to evaporate in a cup in a warm place.

As is obvious from these experiments, *stearine and oleine form the approximate constituents* of fat, and this is the reason why some fats are hard, some soft, and others liquid; the solid stearine predominates in the former, the fluid oleine in the latter. Pure stearine begins to melt at 60° C., pure oleine begins to solidify only at a very low temperature. One pound of mutton contains about three quarters of a pound of stearine; one pound of olive oil barely a quarter of a pound.

The following are among the most important fats:—

A. VEGETABLE FATS.

a. *Drying Oils* (*Varnish Oils*).

534. *Linseed Oil.* — The well-known linseed yields, on being subjected to pressure, a yellow oil, equal to one fifth of its own weight, which is gradually bleached by long exposure to the sunlight. It is most frequently used in oil varnishes.

Experiment. — Add to an ounce of linseed oil a quarter of a dram of litharge, and half a dram of acetate of lead; put the mixture in a warm place, and frequently shake it. The liquid, clarified by settling, now dries much quicker than it would have done before; it is the common *linseed-oil varnish*, which, mixed with colors, is generally used for imparting a gloss to wood, metal, &c. The so-called oil-cloth is cotton cloth smeared with colored varnish; oil-silk is varnished silk. This varnish is commonly prepared, on a large scale, by heating one hundred pounds of linseed oil with one pound of litharge, and maintaining the mixture for an hour at a temperature of 100° C. A stronger heat renders the varnish darker and thicker, and, besides, might easily cause it to boil over and take fire. The slimy, dingy white sediment which remains after both processes is a combination of mucilaginous substances with oxide of lead. All oils contain, in the unpurified state, mucilaginous (gummy and albuminous) substances, which retard the drying; these are rendered insoluble by oxide of lead. Varnish is, accordingly, linseed oil free from mucilage.

By kneading together linseed-oil varnish and chalk, we obtain a plastic dough, common putty.

Hemp oil, from hemp-seed, of a yellowish-green color, is also used in the preparation of varnish, and likewise for burning, and for the manufacture of green soap.

Poppy oil, from poppy-seeds, serves as a table oil, and for the preparation of a very clear varnish.

Castor oil, from the seeds of the castor-oil plant, is a purgative medicine.

Oil is also obtained from pumpkin-seeds, walnuts, sunflower-seeds, &c.

b. Unctuous Oils (remaining viscous).

535. *Oil for burning* is expressed from rapeseed. In order that it may burn without depositing soot on the wick, *it must be* refined, that is, purified from

its slimy parts. This is done, not by oxide of lead, but by sulphuric acid.

Experiment. — Mix one ounce of crude rape oil with eight drops of common sulphuric acid, and shake it frequently; in half an hour add half an ounce of water, again shake the mixture briskly, and set it aside for some days, when the oil floating on the surface will be freed from slime (refined). The slimy parts, charred by the sulphuric acid, and rendered insoluble, are found settled in the water at the bottom of the vessel. The sulphuric acid yet adhering to the oil is removed by repeated washing with water. Sulphuric acid chars, as is known, all organic substances (§ 173), some (for instance mucilage) easily, others (for instance oil) with difficulty; if just enough sulphuric acid, therefore, is added to the oil to char the mucilage, then the mucilage only is destroyed, and the oil remains undecomposed. A larger quantity of sulphuric acid would also attack the oil.

Olive oil is pressed out from the pulp of olives, the fruit of the olive-tree. The finest cold-pressed *Provence oil* is of a bright yellow color, the hot-pressed common olive oil is greenish; these two sorts are, as is well known, universally used as a table condiment, and for greasing machinery. There is a thicker, darker kind, of an inferior quality, which is used in France and Italy for the manufacture of the so-called Naples or Marseilles soap.

Oil of almonds is obtained by subjecting sweet almonds to pressure. Bitter almonds also yield by cold pressure a good oil of almonds, while by hot pressure an oil is obtained containing prussic acid.

Oils are obtained also from hazle-nuts, beech-nuts, *plum* and cherry stones, apple-seeds, &c.

Cocoa-nut oil, from the meat of the cocoa-nut, is, at average temperatures, as soft as hog's lard; it has a white color and a somewhat disagreeable smell.

Palm oil, a yellow fat, similar to butter, likewise proceeds from the fruit of a species of palm-tree. Its yellow coloring matter is removed when heated to 130° C. (bleaching by heat).

Cocoa-nut oil and palm oil are now manufactured into soap in very large quantities.

The following kinds of fat are employed in pharmacy:—

Butter of cacao, the tallow-like white or yellowish fat of the cacao-nut, the cause of the fat particles which rise on boiled chocolate.

Oil of nutmegs, the yellow, agreeably-smelling fat of the nutmeg, having the consistency of butter.

Oil of bays, the beautifully green, suet-like fat of the berries of the laurel-tree.

B. ANIMAL FATS.

536. Our common domestic animals, cows, goats, and sheep, supply us with several kinds of fat;—a harder, white kind (*tallow* or *suet*), which lies in and over the flesh; a softer kind, generally of a yellow color, which separates from their milk (butter); and, besides these, there are the fats of the marrow and the feet.

Stag-grease is white and hard, like *mutton-tallow*.

Hog's lard, *goose-grease*, &c., are well enough known. In earlier times, when it was believed that each single animal fat concealed within itself peculiar properties, numerous kinds of such fats were kept on hand in the apothecaries' shops; but now, plain hog's lard supplies *the place of all the others.*

537. *Fish oil* is tried out from the fat of whales, dolphins, seals, and different fishes. The fat, when melted out at a moderate heat, has a yellow color, and a slight odor, which is not disagreeable; but that which is obtained by strong heat, or from fishes that have become putrid, is of a dark-brown color, and has a very disagreeable odor. Fish oil is preferred for greasing leather; it is likewise used in medicine and in the preparation of the black oil-soap.

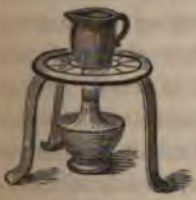
538. *Spermaceti* is white, sparkling, and so hard that it may be rubbed into a powder, and is found inclosed in special cavities in the head of the sperm-whale.

539. *Wax* (cera) occurs in small quantities in all plants, especially in the shining coating of the leaves, stalks, and fruits; for instance, in the skins of apples, and particularly in the pollen of flowers. Some plants of Japan and South America contain so much wax that it may be separated by boiling with water and by pressure, and it is then introduced into commerce under the name of *vegetable* or *Japan* wax. But the purveyors of our common wax are the bees, who gather it from the flowers, and use it in the building of their cells. These insects may, perhaps, make their wax in part also from the sweet juices of the plants on which they feed, for accurate experiments have proved that bees have the capacity of exuding from their abdominal sacs the sugar upon which they feed, converted into wax. The yellow wax is bleached by cutting it into shavings, exposing them to the sun, and frequently watering them. The yellow wax melts at 62° C., the white wax at 70° C. Wax is not only used for imparting stiffness to thread, and in the manufacture of candles, but when dissolved in potash lye it forms the so-called wax-soap, employed for giving a gloss to

variegated paper and for polishing floors, and when mixed with oils is made into plasters and ointments (cerates). Paper immersed in hot wax forms a good material for covering vessels, to protect them from moisture. Turpentine is added to wax, in order to render it more pliant and tougher, as we find it in wax candles, and in the wax used for grafting trees.

FATS AND ALKALIES (SOAPS).

Fig. 207.



540. *Hard Soap.* — *Experiment.* — Make first a *strong lye* with one dram of caustic soda of commerce and one ounce of water, and next, a *weak lye*, with one dram of caustic soda and two ounces of water. Boil the latter gently with an ounce and a half of beef-tallow, for half an hour, in a vessel only half filled with the mixture, and then add the strong lye gradually while the boiling continues. The fat and lye unite by degrees to a uniform mass, of a gluey consistency, which after a time becomes thick and frothy. If a drop of this, when pressed between the fingers, presents firm white flakes, then add half an ounce of common salt, boil for some minutes, and let the whole mass quietly cool. We obtain a firm mass (*soap*) and a watery liquid, in which the common salt and some free soda remain dissolved (*under lye*). If the soap, when boiled with water, forms a turbid solution, it contains still some unsaponified tallow, in which case add to it some weak lye, and continue boiling until the sample gives a clear solution in water; add again some table salt, and let it cool. The soap prepared in this manner has the same

composition as common *house-soap.* More recently, palm oil or cocoa-nut oil has been used partly or entirely to supply the place of tallow, the palm oil because it is cheaper than tallow, and the cocoa-nut oil because it communicates to the soap the property of forming a strong lather.

Experiment. — Repeat the former experiment, using olive oil instead of tallow; hard soap is likewise obtained (*olive oil* or *Marseilles* soap).

541. *Soft Soap.* — *Experiment.* — Prepare again some oil-soap, as above described, but instead of soda use potassa lye, which is prepared from caustic potassa and water, and omit the addition of common salt; the glutinous mass does not hereby pass by boiling into a hard soap, but, after a sufficient evaporation of the water, yields a soft mass (*soft soap* or *potassa soap*). This kind of soap is frequently employed in cotton factories for the cleansing of colored fabrics. If whale oil, hemp-seed oil or linseed oil is used instead of olive oil, a darker-colored soft soap is obtained, which is usually colored green by indigo and turmeric (*green and black soap*).

Ammonia acts far more feebly than potassa and sodium upon fats. If some of the unctuous oils are shaken up with ammonia, thick white mixtures, *liniments*, are obtained, which are often applied by friction to the skin.

Hard soaps are formed from fats by *soda*, *soft* soaps by *potassa*. The chemical process taking place in both cases may be explained as follows.

542. *Fat Acids.* — The fats, as was shown in § 533, consist of several simple, sometimes solid, sometimes fluid, kinds of fat, — among which the solid stearine and the fluid oleine are especially predominant. These proximate constituents of the natural fats may be re-

garded as saline bodies; that is, as combinations of an acid with a base. Every simple fat contains a peculiar acid, — stearine, stearic acid; oleine, oleic acid; palmitine, palmitic acid, &c.; but all contain one and the same base, to which the name *oxide of glyceryle* (sweet principle of oil) has been given.

Stearine is, accordingly, stearate of oxide of glyceryle.
Oleine " " oleate of oxide of glyceryle.
Tallow " " { a mixture of much stearate, and a little oleate of oxide of glyceryle, &c.

To designate the different acids contained in the fats, the general term "fat acids" will always be used in the following pages. *Fats in general are accordingly to be regarded as combinations of fat acids with oxide of glyceryle, or as salts of fat acids and oxide of glyceryle.*

543. *The process of the formation of soap* is thus one of simple elective affinity; the stronger bases, soda and potassa, displace the weaker oxide of glyceryle, and combine with the fat acids, forming compounds of fat acids with soda (*soda soap*), or of fat acids with potassa (*potassa soap*). From potassa and fat acids with oxide of glyceryle are formed fat acids with potassa and free oxide of glyceryle (potassa soap). From soda and fat acids with oxide of glyceryle are formed fat acids with soda and free oxide of glyceryle (soda soap).

In the first two experiments the separated oxide of glyceryle, soluble in water, remains in the under lye; but in the soft soap, when the surplus of water does not separate as a fluid from the soap, but is removed by evaporation, it remains mechanically mixed with the soap.

The action of common salt may be seen by trying *to dissolve* hard soap in salt water; no solution takes place, not even on boiling, *for soap is insoluble in salt water*, and likewise in strong lye; therefore, soap may be precipitated from a solution in water by the addition of common salt. This method of separation is usually employed on a large scale, since it yields a purer soap than when the water is removed by evaporation; for, in the latter case, hydrated oxide of glyceryle, surplus of lye, and perhaps, also, some impurities contained in the lye or fat, remain mixed with the soap, while by the former method they are dissolved in the liquid (*under lye*).

544. *Conversion of Potassa Soap into Soda Soap.*—*Experiment.*—Dissolve some of the soft soap obtained in § 541 in boiling water, and sprinkle in some salt; the soap separates, and collects upon the surface of the water, yet, when cold, it will no longer be soft, but hard. The salt here acts in another manner; it occasions an interchange of the constituent parts; namely, from fat acids with potassa and chloride of sodium are formed fat acids with soda and chloride of potassium (soda soap).

Soap-makers often proceed in this way on a large scale; they make a caustic potassa lye of wood-ashes and lime (lye of wood-ashes), boil it with fat, and finally convert the soft potassa soap obtained into hard soda soap, by means of common salt.

SOAP AND ACIDS.

545. *Experiment.*—Dissolve some of the hard soda soap in hot water, and add to it vinegar by drops until a turbidness ensues. Vinegar, and other acids, are *stronger* than the fat acids; therefore, they withdraw from the latter the base, and the fat acids are set

free. As these are lighter than water, and at the same time insoluble in it, so they collect on the surface of the water. The fat acids thus obtained resemble tallow externally, but it is evident that they are not tallow, since, even after long washing, they still have an acid reaction, which is not the case with tallow, and they are easily dissolved in hot alcohol, but tallow very difficultly. Three fourths of the mass consists of stearic acid, one fourth of oleic acid. When strongly pressed between blotting-paper, the oleic acid soaks into the paper, and the stearic acid remains behind.

Stearic acid is harder and more brittle than wax, brilliantly white, translucent, and melts at the temperature of 70° C. There are now large factories for the preparation of it, and it is used in the manufacture of the stearine candles, which have become so popular.

Experiment. — Heat some ounces of strong alcohol in a water-bath, and when it boils, add to it as much stearic acid as will dissolve in it. Pour half of the solution obtained into cold water, and let the other cool quietly; in the former case the stearic acid is obtained as a light, silky, brilliant mass, while in the latter it takes the form of delicate crystalline plates.

Fig. 208.

546. *Experiment.* — If an acid is added to a solution of oil-soap, an oily fluid separates, which consists principally of oleic acid.

Oleic acid in its external appearance is hardly to be distinguished from olive oil, but it differs from it in the following respects: it has an acid taste and reaction, which olive oil has not, and it readily dissolves even in cold alcohol, while olive oil does not. The oleic acid, procured in stearic-acid factories from tallow, as a secondary product, now frequently occurs in commerce, and on account of its cheapness is employed in the manufacture of soap, and in greasing wool for spinning.

547. *Oxide of glyceryle* (glycerine, or sweet principle of oil). — *Experiment.* — Add to the soft soap, prepared according to § 541, a solution of tartaric acid, and leave the watery fluid, after being clarified by filtration, to evaporate in a warm place. The saline mass remaining after evaporation consists of bitartrate of potassa (tartar) and of the base of the fats, oxide of glyceryle; when strong alcohol is added, the latter dissolves, while the bitartrate of potassa, together with any excess of tartaric acid that may be present, remains undissolved.

The oxide of glyceryle, which remains after the evaporation of the alcohol, has the appearance of a yellow syrup. It has not an alkaline taste, but is sweet, like sugar; neither does it react basically, although it is soluble in water. It has, accordingly, no similarity to other bases soluble in water, as, for example, potassa or soda. But the reason why it is regarded as a base is evident from its behaviour with acids; it is considered as a base, because it combines with acids in fixed proportions, forming compounds having the character of salts. It constitutes only about a tenth or twelfth part of fats; an ounce and a quarter of it, at most, is contained in one pound of tallow.

Experiment. — Wipe the bowl containing the small quantity of the oxide of glyceryle that has been obtained with white blotting-paper, and heat the latter in a spoon. During the combustion there will be evolved from it an extremely pungent odor, proceeding from the oxyde of glyceryle, which is decomposed by the heat into a volatile, extremely pungent substance (*acroleine or oxide of acryle*), which causes lachrymation. Hence is explained the pungent odor which is perceived during the imperfect combustion of all kinds of fat. This odor is very strikingly manifested, also, when varnished articles are drying; for instance, in the drying chambers of the oil-cloth factories. This volatile matter may be formed also, even at a low temperature, from glycerine. No smell of acroleine is evolved on heating the pure fat acids.

PROPERTIES OF SOAPS.

548. *Washing with Soaps.* — Soaps have two important properties; — 1st, they dissolve fat and oils; 2d, they are very easily resolved, merely by mixing with much water, into an acid salt and free alkali; the latter dissolves, as is well known, most organic substances, but the former effects by its lubricity an easy washing away of the dissolved matter from other substances. On these two properties depends the application of soap in washing. The separated acid salt of fat acids with alkali modifies at the same time the action of the free alkali, and keeps the articles pliant which are washed with soap, while they would become fragile if they were cleansed with caustic alkalies alone. To prevent the shrinking of woollen articles, wash them with a weak solution of carbonate of soda, instead of with soap.

549. *Soap and Alcohol.* — *Experiment.* — Pour one ounce of alcohol upon one ounce of the shavings of tallow soap; the soap is completely dissolved on heating in the water-bath, but the solution congeals on cooling *to a transparent jelly.* This jelly-like soap, mixed

with camphor and ammonia, is called *opodeldoc.* The white stars separating from this consist of crystallized stearate of soda. All soaps prepared from solid fats (rich in stearine) behave like tallow soap.

Experiment. — Dissolve one dram of Naples soap in half an ounce of alcohol; this solution does *not* coagulate on cooling; it forms the *tincture of soap.* By evaporation, a diaphanous soap is obtained (*transparent soap*). All the soaps made from the fluid fats (rich in oleine) act like the Naples soap.

550. *Insoluble Soaps.* — *Experiment.* — If some lime-water is added to a solution of soap in water, a precipitate of insoluble lime soap is formed; hence is explained why spring-water, which generally contains lime (hard water), neither dissolves soap nor lathers with it, and accordingly cannot be used for washing.

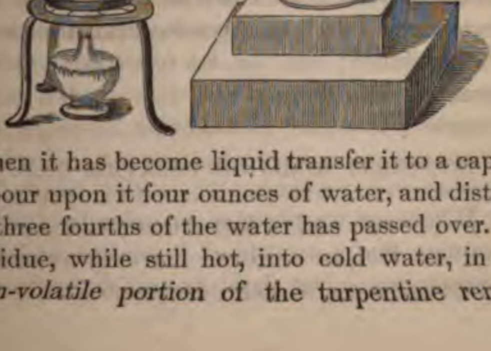
Experiment. — By adding acetate of lead (§ 337) to a solution of Naples soap in hot water, as long as a precipitate is formed, we obtain, by double elective affinity, acetate of soda, which remains dissolved, and a compound of fat acid with oxide of lead, which separates as a white, adhesive mass, that may be kneaded with the moist hands, and formed into rolls (*lead soap* or *lead plaster*). From the compound of fat acid and soda, and from the acetate of lead, are formed a compound of fat acid with oxide of lead (lead plaster) and acetate of soda.

In pharmaceutic laboratories, this plaster, generally known under the name of *diachylon*, is prepared in a different manner, namely, by boiling litharge with olive oil and some water. By this method oxide of glyceryle is readily obtained, and in larger quantities, as a secondary product; the plaster made has only to be washed with hot water, and the water evaporated after the oxide of lead dissolved in it has been previously precipitated by sulphuretted hydrogen. If, instead of litharge, white lead (carbonate of lead) is boiled with oil and water, we likewise obtain a compound of fat acid and oxide of lead, since the carbonic acid is expelled by the fat acids. In this manner the *plaster of carbonate of lead* is prepared, which has commonly a whiter color than the former plaster, because it still contains some white lead mechanically mixed with it.

X. VOLATILE OR ETHEREAL OILS.

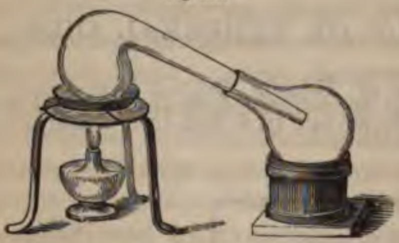
551. *Preparation of Volatile Oils.* — *Experiment.* — Put one ounce of turpentine in a dish in a warm place,

Fig. 210.



and when it has become liquid transfer it to a capacious flask, pour upon it four ounces of water, and distil until about three fourths of the water has passed over. Pour the residue, while still hot, into cold water, in which *the non-volatile portion* of the turpentine remaining behind congeals to a solid mass (*resin*). A strong-smelling, colorless liquid, a volatile oil, commonly known under the name of *oil of turpentine*, floats on the surface of the water distilled over. Turpentine, a juice which exudes from pines, larches, and other trees, when the inner bark is cut through, is accordingly a mixture of resin and oil of turpentine; the latter is converted by heat, simultaneously with the water, into steam, and on cooling is again condensed to a liquid.

Fig. 211.



Experiment. — Distil in the same manner half an ounce of cumin-seeds (which have been previously bruised in a mortar), in a retort containing four ounces of water, until two ounces of water have passed over. The drops floating upon the water are likewise a volatile oil, *oil of cumin;* they have the smell and taste of the cumin-seeds, but in a stronger degree, while the residue remaining in the retort has scarcely the least smell or taste of them. All volatile oils possess a burning taste, and are somewhat harsh to the touch; but the fat oils have a mild taste and an unctuous feeling.

DIFFERENT KINDS OF VOLATILE OILS.

552. Whenever we perceive an odor in a plant, we may presume that a volatile oil is present, which gradually evaporates. But how incredibly diffused and

diluted this must be in many plants may be inferred from the fact, that scarcely a quarter of an ounce of volatile oil is contained in one hundred pounds of fresh roses, or orange blossoms. We most frequently find the volatile oils in the flowers and seeds, sometimes in the stalks and leaves, but more rarely in the roots. They are obtained almost in the same way, without exception, as oil of turpentine, by distilling the vegetable parts with water. The oils procured from the skins and peels of some fruits, as the oil of lemons, and bergamot, contained in the rind of lemons, citrons, and oranges, form an exception, since such oils are obtained by expression from the fresh rind.

553. Of the more known volatile oils we obtain, —

a.) *From the flower :* —

Oil of roses, a yellowish, thick fluid, with flakes resembling tallow floating in it.

Oil of orange-flowers (*ol. neroli*), colorless, reddish in the light; contains no oxygen.

Oil of camomile, a dark blue, thick liquid; becomes green, and finally brown, by age and light.

Oil of lavender, a yellowish, thin liquid.

Oil of cloves, yellowish, soon becomes brown; a somewhat thick fluid, heavier than water.

b.) *From seeds and fruits :* —

Oil of cumin, colorless; becomes yellowish, and finally brown, by age.

Oil of anise-seed, yellowish; congeals even at 12° C.

Oil of fennel, colorless or yellowish; congeals likewise readily.

Oil of dill, yellow; becomes brown in the light.

Oil of nutmeg, a pale yellow, thin liquid, has the smell of nutmegs.

Oil of bitter almonds, yellow; heavier than water;

contains prussic acid, and consequently is *very poisonous.*

Oil of mustard, yellowish, of an extremely pungent smell, causing lachrymation; contains sulphur.

Oil of juniper, colorless; contains no oxygen.

Laurel oil, white or yellow; a thick fluid.

Oil of savin, colorless or yellowish; a thin fluid; contains no oxygen.

Oil of parsley, pale yellow; on being shaken with water, separates into a light volatile oil, and into a heavy, solid, crystalline oil.

Oil of lemons, from lemon-peels, contains no oxygen.

Oil of orange-peel likewise contains no oxygen.

Oil of bergamot, from the rind of the bergamot orange, a pale yellow, very thin liquid.

c.) From the leaves and branches: —

Oil of the curled leaf mint (Mentha crispa), colorless or yellowish; becomes brown with age.

Oil of peppermint, colorless or yellowish, a very thin liquid, now frequently exported to Europe from America.

Oil of balm, pale yellow, has an odor like that of lemons.

Oil of marjoram, yellowish or brownish.

Oil of thyme, when fresh, yellowish or greenish; when old, brownish-red.

Oil of sage, when fresh, yellowish or greenish; when old, brownish-red.

Oil of wormwood, dark green; soon becomes brown or yellow, and viscous in the light.

Oil of rosemary (*ol. anthos*), colorless and very thin, is, next to the oil of turpentine, the cheapest volatile *oil.*

Cajeput oil, from the leaves of a tree growing in the

Moluccas; the oil, when pure, is colorless; the crude oil is commonly green, and often contains camphor; it has a camphorated odor.

Oil of rue, pale yellow, or greenish.

Oil of cinnamon, yellow; soon becomes brown in the air; heavier than water.

Oil of turpentine, the most common of the volatile oils, is contained in all our fir-trees, and exudes from them, mixed with resin, as turpentine (§ 568). When purified, it is colorless and thin, and has an agreeable, penetrating odor; it contains no oxygen. An ordinary sort, possessing a disagreeable empyreumatic odor, obtained in the preparation of pitch from pine resin, is *crude oil of turpentine.*

Camphor occurs in commerce as a solid white, crystalline, odoriferous mass, prepared by distillation with water, or by sublimation from the wood of the camphor-tree, growing in Japan and the East Indies.

d.) *From roots:* —

Oil of acorus, yellow or brownish.

Oil of valerian, pale yellow, or greenish; becomes rapidly brown and viscous on exposure to the air.

It is very remarkable, that we sometimes find several sorts of oil in one and the same plant. Thus, for example, we find in the orange-tree three different kinds of oil; one in the leaves, another in the blossom, and a third in the rind of the fruit.

554. *Ferment Oils.* — *Experiment.* — If water is poured on the centaury-plant (Erythræa centaurium), and it is left in a warm place until fermentation commences, a very penetrating odor is evolved from the leaves, which were previously scentless; the odor proceeds from a volatile oil, which was generated during *the fermentation.* In a similar manner, the fresh, scent-

less leaves of the tobacco-plant obtain the well-known nicotian odor by the so-called sweating process. Oils of this kind, which may be generated by fermentation from many other odorless plants, are called *ferment oils.*

In the brandy-distilleries there is evolved also, on the fermentation of potatoes and grain, a disagreeably-smelling oil (*fusel oil*), which partly distils over with the brandy or spirit, and imparts to these liquids the fusel taste and smell. On filtering through charcoal, it remains behind in the pores of the latter.

555. *Empyreumatic Oils.* — Finally, oily volatile substances are produced by the dry distillation of vegetable and animal matter; for instance, oil of wood-tar from wood, coal oil from pit-coal, animal oil from bones, oil of amber from amber, &c. They are all distinguished by an exceedingly disagreeable odor, and are mixtures of various volatile substances. They are called *empyreumatic oils.*

Rock oil, or *petroleum* (πέτρος, rock), is of a similar nature; it oozes out from the earth in many places in Asia, where it is formed in a manner as yet unknown to us. The red color of the oil occurring in commerce is given to it by the addition of alkanet-root.

PROXIMATE CONSTITUENTS OF THE VOLATILE OILS.

556. All these oils are *volatile* at average temperatures, except camphor, which begins to melt at the temperature of 175° C.; but below this temperature forms a white, solid, crystalline mass. If the volatile oils are cooled, there is frequently separated from them a beautifully crystallized, solid, white, camphor-like substance, which has been called *stearoptene*, in opposition to the liquid portions that remain, which are called

eleoptene. Accordingly, the volatile oils, like the fats, consist of two proximate constituents, one of which may be regarded as solid and crystallized, but the other only as a liquid. Many oils — for instance, the oils of rose and anise-seed — are so rich in stearoptene, that, when kept in cool cellars, they congeal into a nearly solid mass.

ELEMENTARY CONSTITUENTS OF THE VOLATILE OILS.

557. The volatile oils are divided into three classes, according to the elements of which they are composed: —

a.) Into the *non-oxygenated* oils (having two elements); these consist only of carbon and hydrogen (C, H), so that they may be regarded as condensed illuminating-gas. To this class belong rock oil and oils of turpentine, juniper, savin, lemons, &c.

b.) Into *oxygenated* oils (having three elements), which, beside *carbon* and *hydrogen*, contain also *oxygen* (C, H, O); most of the other volatile oils have this constitution.

c.) Into *sulphuretted* oils, which are composed of *carbon*, *hydrogen*, and *sulphur* (sometimes with and sometimes without *nitrogen*). The oils of this class are distinguished by a very pungent smell, causing lachrymation, and by a great acridity, raising blisters on the skin when brought in contact with it. The oils of mustard, horseradish, scurvy-grass, garlic, hops, &c. belong to this class.

Of these elements, hydrogen (as regards the number of atoms) commonly predominates; hence, the volatile oils are usually reckoned among the organic substances *rich in hydrogen*.

PROPERTIES OF THE VOLATILE OILS.

558. *Experiment.*— Pour a drop of some volatile oil upon a sheet of paper, and let it remain exposed to the air; the paper at first receives an apparent grease-spot, but this disappears after a time, because the oil gradually evaporates. The name *volatile* or *ethereal oil* thus explains itself; and the disappearance of camphor, on being exposed to the air, is owing to this volatileness.

If the oiled paper is placed upon a warm stove, the evaporation takes place much more rapidly. Aromatic oils are employed in this way for perfuming apartments. Usually a quantity of flowers, wood, and rinds, finely cut up, are moistened with the oil, and scattered as a *fumigating powder* upon the stove.

559. *Experiment.*— Heat a quarter of an ounce of oil of turpentine in a vessel to boiling. A thermometer introduced into the liquid will indicate a temperature of about 150° C.; oil of turpentine accordingly requires half as much again heat for boiling as water. Other oils often boil with even more difficulty. The vapor may be inflamed by a taper, when it will burn with an intense sooty flame; it is easily extinguished by covering the vessel with a board, but *water must on no account be employed for extinguishing burning oils.* Then remove the oil from the fire; after it is cold, mix it with some water, and again heat it; as long as any water is present, the temperature of the fluid will not rise above 100° C. The ascending vapor is a mixture of aeriform water and aeriform oil. The same thing occurs here as previously mentioned; the less volatile oil evaporates with the more easily volatile water. *The oils* remain unchanged at the boiling point of water, but at their own boiling point (140° to 200° C.)

they become not unfrequently somewhat empyreumatic; this is the reason why water is always added in the preparation of oils, and also in the redistillation of them (*rectification*).

560. *Experiment.* — Inflame some drops of oil of turpentine put upon a shaving, and also a piece of camphor laid upon water; both bodies will ignite, and burn with a highly luminous and sooty flame. The volatile oils are far more easily combustible than the fat oils, which in order to burn with a flame must be heated to 350° C. We have consequently in oil of turpentine a convenient means for speedily lighting oil-lamps; it being merely necessary to smear the wick with a few drops of it.

Experiment. — Pour a mixture of half an ounce of absolute alcohol with half a dram of oil of turpentine into a spirit-lamp; the mixture gives, when lighted, a strongly illuminating, but no longer a sooty flame, since all the carbon of the oil of turpentine is converted by the heat of the burning alcohol, rich in hydrogen, into illuminating gas, and then into carbonic acid (and water). This mixture is now used in lamps constructed for the purpose, and which are so made that the liquid evaporates in them, and the vapor ignites as it issues from several small openings.

561. *Volatile Oils and Water.* — *Experiment.* — Drop some oil of cumin upon water; the oil floats on the surface without mixing with the water, for most of the volatile oils are *lighter* than water; but there are some, such as oil of cinnamon, oil of cloves, and oil of bitter almonds, which are heavier than water, and sink in it.

If the mixture is briskly shaken, the water becomes *turbid, because the oil is* thus divided into small, invisible globules, which are kept suspended in the water. The water may be again clarified by filtration, but it retains the smell and taste of the oil, since a small quantity of it remains dissolved. Many such solutions are kept in the apothecaries' shops, under the name of *medicated* or *distilled waters.* It is well to keep them protected from the light, and in full vessels,—both light and air having a decomposing action on the volatile oils. They are commonly prepared by distilling with water the vegetable substance containing the oil, as thereby a more intimate combination of the water with the oil is effected than by merely shaking it up.

562. *Volatile Oils and Alcohol.*—*Experiment.*—Add a drop of oil of cumin to one ounce of strong alcohol; it dissolves readily and entirely. All the volatile oils are soluble in alcohol, most of them in alcohol of eighty per cent.; but the non-oxygenated oils, such as oil of turpentine, oil of lemons, &c., only in absolute alcohol. If an ounce of water, in which half an ounce of sugar has previously been dissolved, is added to the solution, we obtain cumin-cordial. In this manner, by the aid of various aromatic oils, the innumerable *cordials* occurring in commerce are now generally prepared (preparation of cordial in the cold way). They were formerly manufactured from aromatic seeds, flowers, herbs, &c., by pouring brandy over them, the brandy being afterwards distilled or drawn off, whereby a spirituous solution of volatile oils was likewise obtained.

Experiment.—If some drops of bergamot, orange-flower, lavender, or rosemary oils are dissolved in half an ounce of strong alcohol, we obtain a spirit of a very pleasant odor. In a similar way the innumerable kinds of perfumed waters are prepared, at the head of which stands the well-known *eau de Cologne.* The fumigating spirit also, which, instead of the fumigating powder, is often sprinkled on a warm stove, has a similar composition. Camphor spirit, much used as an external remedy, is likewise a solution of camphor in alcohol.

563. The volatile oils are not only dissolved by alcohol, but also by *ether* and concentrated *acetic acid.* A solution of oil of cloves, cinnamon, bergamot, and thyme, in acetic acid, is used as a *perfumed vinegar*, on account of its refreshing odor.

The volatile oils may also be mixed with *fat oils*, and with some kinds of tallow and lard; hence by means of them an agreeable odor may be imparted to the latter, as, for instance, in hair oils, pomatum, &c., or grease-spots be dissolved and removed by them from various articles. Volatile oils mixed with alcohol yield, when shaken up with olive oil, a turbid, milky liquid, because the alcohol does not dissolve the olive oil; this behaviour may be taken advantage of for testing the purity of mercantile oils.

564. *Experiment.* — Rub a piece of sugar some time on the rind of a fresh lemon; the hard sugar tears the cells in which the oil of lemons is inclosed, and the oil is attracted into the pores of the sugar. This, when reduced to powder, is called *oleo-saccharum.* Such mixtures are commonly prepared in pharmacy by triturating together powdered sugar and volatile oils.

565. *Experiment.* — If you add some drops of oil of turpentine to *iodine*, a brisk emission of sparks ensues, since a part of the hydrogen is expelled and replaced by the iodine. The same phenomenon is occasioned by all non-oxidized oils, but not by the oxidized; therefore iodine may serve as a test, although not a very

accurate one, for ascertaining whether oils of the latter class have been adulterated with oil of turpentine.

566. *Conversion of the Volatile Oils into Resins.—Experiment.*—Let some oil of turpentine remain exposed to the air for some weeks, in a cup covered with paper, and afterwards put the cup in a warm place to evaporate the oil; it will not entirely volatilize, but will leave at first a viscous, and afterwards a vitreous residue. This residue is resin. *All volatile oils are converted into resin, because they gradually absorb oxygen from the air;* which, as in the case of the transformation of alcohol into vinegar, first combines with a portion of the hydrogen of the oil, forming water, and then unites with the oil itself. Alcohol, on exposure to the air, is converted by the removal of hydrogen into aldehyde, then by the reception of oxygen into acetic acid; the volatile oils are, in a similar manner, first converted by the air into *turpentine* (mixtures of volatile oils and resin), and then into *resins*. Oil of turpentine consists of $C_{10}\,H_{16}$; resin, of $C_{10}\,H_{15}\,O$; consequently the former has only to relinquish one atom of hydrogen, and receive one atom of oxygen, to be converted into resin. This explains very simply why the volatile oils become gradually viscous and scentless on being kept, and more rapidly in large and only partially filled bottles than in small ones, and why the drops running down on the outside of the bottles dry up first into a sticky, and then into a resinous mass. Old oil of turpentine is, for this reason, not suitable for removing grease-spots; it dissolves, indeed, the fat or resin dried into the material, but leaves behind new spots of resin in their place.

The volatile oils are very rapidly changed by nitric acid into non-volatile resinous substances. There are sometimes simultaneously formed, in this case, peculiar *organic acids;* for example, turpentinic acid from oil of turpentine, camphoric acid from camphor, &c. Many such acids are also spontaneously generated together with resin, by long standing in the air; for instance, cinnamic acid in the oil of cinnamon; or are found already formed in the volatile oils; as, for instance, caryophyllic acid in oil of cloves, &c.

567. Metallic arsenic has no smell; neither has arsenious acid (arsenic combined with oxygen). We perceive the striking odor like that of garlic only at the very moment when the arsenic is combining with the oxygen. The same thing seems to happen with regard to the odor of volatile oils, so that we may assume that the odor is emitted *because* the oils are combining with the oxygen of the air, and while they are combining. Fresh oils, and those distilled by exclusion of air, and old resinous oils, either do not smell at all, or emit quite an unusual odor.

XI. RESINS AND GUM-RESINS (RESINÆ ET GUMMI-RESINÆ).

568. *Turpentine and Balsams.*—Whoever has been in a forest of fir or pine trees must certainly have noticed the yellow, transparent juice, having the consistency of honey, which exudes from these trees, and he may perhaps have observed also that it sticks to the fingers, and cannot be washed off again by mere water. This juice is *turpentine.* It is procured in large quantities by incisions made in the trees. That obtained *from the European* fir-trees is turbid, and has a thick

consistency; it is called *common European turpentine;* but *Venice turpentine* is the more transparent and more fluid sort, which is procured from larch-trees. A yet finer quality, yielded by the American silver-fir, is called *Canada balsam.*

The term *balsam* is applied also to several other resinous vegetable juices, which exude from some tropical trees, or are boiled out from them. The best known are the yellowish *balsam of copaiba*, an important medicine, the blackish-brown *balsam of Peru*, and the brownish-gray *balsam of storax* (liquid storax), the last two of which are generally used for fumigating, on account of their agreeable odor, which resembles that of vanilla.

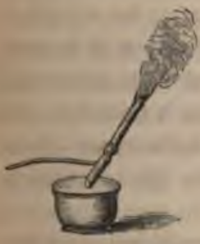
All these turpentines and balsams are to be regarded as solutions of resin in volatile oils, into which two constituents they are separated when distilled with water (§ 551). The same thing happens when they are allowed to stand for some time in an open vessel in a warm place, except that in this case the oil volatilizes, and diffuses itself in the air.

569. *Preparation of the Resins.* — *Experiment.* — Spread a little turpentine upon a board, and put the board for some time near a heated stove; the oil of turpentine evaporates, but the *resin* remains behind as an amorphous brittle mass. In some countries, incisions are made through the bark of the pine-trees, and the turpentine which exudes is allowed to evaporate on the trees themselves, and after it has been purified, by melting and straining through a colander, from the woody particles adhering to it, it is brought into market under the name of *resin*, *white pitch*, or *Burgundy pitch.* Large quantities of such resin are now exported from the forests of America (American resin).

Two different operations are going on during the evaporation of the turpentine; a part of the volatile oil found in it evaporates, and occasions the peculiar smell of the pine forests, but another part attracts oxygen from the air, and is converted into resin (§ 556).

Resinous juices, which harden in the air, forming solid resins, exude, either spontaneously or through incisions made for the purpose, not only from our fir-trees, but also from many other trees and shrubs, particularly those of hot climates. Almost all the resins occurring in commerce are procured in this manner.

Fig. 212.



Experiment. — Resin is deposited most abundantly in those parts of the trees where the branches join the trunk; wood impregnated with such resin is called resinous wood. If a piece of resinous wood is lighted at the upper end, and held by a wire in an oblique position over a basin of water, one portion of the resin burns up with a sooty flame, while another part is melted by the heat, and runs down into the vessel beneath. *Resin is not soluble in water;* hence it hardens in the latter without mixing with it. In this manner — *by roasting* — resins may be prepared from many plants; but the color of the resins thus prepared is usually dark, because some of the resin has become burnt, and is thereby richer in carbon, according to the general law, that hydrogen is always burnt before carbon.

Experiment. — Pour strong alcohol upon some resinous wood, and let it remain for a day in a warm place; the resin is dissolved, and the woody fibre remains behind. The solution is poured into eight times its quantity of water, which is thereby rendered milky, because the resin is precipitated, but in such a state of fine division that it floats about in the water in the form of small globules. If this milky fluid is heated to the boiling point, the resinous particles soften and unite with each other in small lumps, which may be taken out and pressed together in larger masses. This is a third method of extracting resin from vegetable substances.

DIFFERENT SORTS OF RESIN.

570. The following are the most important resins: —

Pine-resin is the resin of our pine-trees.

Galipot is a very clear yellowish-white kind of pine-resin, imported from France.

Copal is of a yellowish-white color, turning to brown, and very hard; it comes to us covered with sand and earth, from which it is freed by washing it with lye and by scraping. The copal of the West Indies and Africa has a smooth surface, but that of the East Indies is wrinkled and uneven. It is insoluble in common alcohol, but it partly dissolves in absolute alcohol, and dissolves entirely in ether; the East India copal dissolves the most readily.

Dammara resin (*Kauri* or *Cowdee*) is colorless or yellowish, tolerably hard; comes from the East Indies.

Mastic is yellowish, transparent, comes in rounded tears, and exudes from a species of Pistacia, a tree growing principally in Greece.

Sandarach, much resembling mastic, but yet more brittle, is the product of an evergreen tree which grows in Africa.

Lac exudes from several species of Ficus growing in the East Indies, through punctures made by a small insect called the Coccus lacca.

a.) *Stick-lac* is the name given to the juice dried upon the twigs.

b.) *Seed-lac*, when it is broken off from the twigs.

c.) *Shellac*, when it is melted and strained through a cloth to remove impurities. The liquefied resin is commonly made to drop upon large leaves, and cooled; it thus spreads out into thin plates. The finest shellac has an orange color, that of inferior quality a dark-brown color. It is very hard and tenacious, and for this reason is generally used in the manufacture of sealing-wax.

Benzoin flows from incisions made in a tree of the East Indies. The resin exuding during the first three years forms milk-white grains, but that formed afterwards is yellow or brown. Both sorts are kneaded together; hence the amygdaline appearance of the common benzoin. Its agreeable odor, somewhat like that of vanilla, has rendered it a popular ingredient in fumigating pastilles, and also in cosmetic lotions for beautifying the skin. One sixth of it consists of benzoic acid.

Dragon's-blood is a brownish-red colored resin; it is the produce of several palm-trees growing in the East Indies.

Guaiacum, a brownish-green resin, and also an olive-colored variety of the same, are obtained by roasting guaiacum-wood, and are considerably used in medicine.

Resin of jalap is extracted by alcohol from the root of the jalapa.

Many other resins are used in pharmacy, for instance, anime, tacamahac, elemi, &c.

571. *Bitumen.* — Two other resins, amber and asphaltum, which are obtained from the earth or from the sea, remain to be mentioned.

Amber probably proceeds from the forests of a primeval age, which have been submerged by floods of water. The resins form an exception to the general rule, — they do not putrefy or decay, like other organic bodies. The amber-resin might accordingly remain for centuries unchanged in the earth, or in the sea, while the trees from which it exuded were changed into mould and earth, or, chemically speaking, became decomposed into carbonic acid, water, &c. Amber is found most frequently in the Baltic and on its coasts, and in many brown-coal mines. Its hardness and tenacity are well known, since it is formed into various articles which are usually manufactured from glass or horn. It differs from other resins, as it yields on fusion *succinic acid*, and undergoes a change, in consequence of which it then becomes soluble in alcohol and oils, which scarcely attack it in its unmelted state. By longer fusion it becomes black, and is then called *amber-colophany;* it yields, at the same time, a very disagreeably smelling empyreumatic oil, oil of amber, which is sometimes used in medicine.

Asphaltum, or *pitch of Judea*, is likewise a mineral resin, which is found in many of the seas of Asia, particularly in the Dead Sea. It has a black color, and great similarity to the black resin which is obtained by the evaporation of pit-coal tar (*factitious asphaltum*). Asphaltum is found in other places, and has a soft consistency, and resembles turpentine (*Barbadoes tar*); this kind has in later times been mixed with sand and lime for making artificial pavements and tiles. It is very probable that these two resins, as also petroleum, are derived from layers of pit-coal which have been heated in the interior of the earth by volcanic fires.

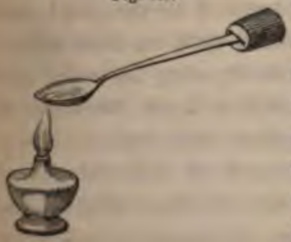
572. Similar resinous substances, of a black color and disagreeable odor, are also artificially formed whenever animal and vegetable substances are heated with an insufficient supply of air, especially during dry distillation of the same. When in a fluid form they are called *tar;* in a solid form, *black pitch.*

PROPERTIES OF RESIN.

573. It was stated when speaking of amber, that resins are substances which *do not undergo decay;* indeed, they have the power to protect from decomposition other bodies which very readily pass into decay or putrefaction, — for instance, flesh. On this account they were formerly used for embalming dead bodies, which are now found, after the lapse of centuries, dried to mummies, in the pyramids of Egypt.

574. *Resin and Water.* — The resins as a general rule are *insoluble* in water, and therefore tasteless; but some of them in very small quantities may be dissolved, and these usually have a bitter taste. But many of the resins which occur in commerce contain some water in a state of minute division, and are thereby rendered dull and opaque; common pine-resin and boiled turpentine furnish examples of this.

Fig. 213.



Colophony or Rosin. — *Experiment.* — Heat a piece of the solid turpentine (§ 551), or else some pine-resin, in a spoon, till all the water is evaporated; the *anhydrous resin* will now appear perfectly transparent. In this state it is called *colophony*, or *rosin*, being *white* when it is moderately heated, but *brown* when the heat is so strong as to convert a part of the resin into *black pitch*. Colophony is so brittle, that it may easily be reduced to a powder. When the bow of a violin is rubbed with it, the rosin powder formed remains adhering to the fibres, and these then again adhere better to the strings of the violin. A similar effect is produced on the cords which sustain the weights in clocks when they are rubbed with rosin to prevent their slipping. The resins, accordingly, exert an effect contrary to that of oil; by resin, a rough, uneven surface is produced, by oil, a smooth, slippery surface.

575. *Action of Heat on Resins.* — The experiment first performed reveals at the same time another property of resin, namely, its easy *fusibility*. Most of the resins require, in order to become fluid, a heat which is somewhat higher than that of boiling water. If the melted rosin is poured upon a board, it spreads, and forms after hardening a solid, brilliant coating on the wood. The resins are hereby well adapted for protecting wood or metal from the penetration of air or water. For this reason, iron rails and iron ornaments are covered with a coating of pitch, to prevent them from being so quickly oxidized by the oxygen of the air; for the same reason, also, wine-casks and beer-barrels are smeared with pitch, that no air may penetrate into the casks, and that no beer may penetrate into the staves. The wood-work of ships, the hatches, &c., are covered with tar to keep out the sea-water and rain; and finally, also, the solid and tenacious resin, shellac, is employed in the form of sealing-wax as a protection against curiosity.

Sealing-wax. — *Experiment.* — Melt together in a small ladle one fourth of an ounce of pale shellac, one dram of turpentine, one dram of cinnabar, and three fourths of a dram of prepared chalk; scrape out the mass while yet ductile, and roll it out into sticks by the hands, moistened with water. The turpentine renders the sealing-wax more inflammable, and the cinnabar imparts to it the favorite red color. Various other colors are given to it by chrome-yellow, azure-blue, mountain-green, lamp-black, bronze-powder, &c.

576. *Rosin-gas.* — *Experiment.* — When rosin is heated above its melting point, it *kindles* and *burns* with a luminous and sooty flame, leaving behind some charcoal. Therefore powdered rosin, when blown into the flame of a lamp, burns vividly. In many places *illuminating gas* is prepared from it, by letting it drop in a melted state upon coke, which is heated to redness in an iron cylinder (*rosin-gas*).

Burnt Pitch. — If the rosin, after it has burnt for some time, is extinguished by putting a board over it, we shall have as a residuum a black, burnt resin, *ship-pitch*, and *shoemaker's wax*, possessing great tenacity.

Lamp-black. — *Experiment.* — If you hold a cone made of blotting-paper over burning pine-wood, it will soon become lined with soot. The well known *lamp-black* is prepared on a large scale by a similar method. Resinous wood, or the resin itself, is burnt with an insufficient supply of air in a stove furnished with long flues, or with a chamber in which the smoke deposits its carbon on its passage through.

Experiment. — If some amber is scattered on glowing charcoal, a vapor having a pleasant balsamic odor is emitted from it as it smoulders away. Amber, frankincense, benzoin, and mastic are on this account frequently used for fumigating purposes.

577. *Electrophorus.* — *Experiment.* — Rub a stick of sealing-wax for some minutes upon a piece of cloth,

and then approach it to some small shreds of blotting-paper; they will fly up to the sealing-wax, and remain adhering to it for some time. This attraction is effected by electricity (*resinous* or negative electricity), which is generated in the resins by friction. If you pour a mixture of shellac and rosin into a tin plate in order to obtain a larger surface, you will be enabled to extract the electricity from it in the form of sparks, and to collect it; this is called an *electrophorus* (bearer of electricity). This mysterious power has received the name of *electricity* from ἤλεκτρον, the Greek word for amber, in which the electrical phenomena were first observed.

578. *Resin and Alcohol.* — *Experiment.* — Wrap half an ounce of sandarach in paper, and break it with a hammer into smaller pieces; then mix it with an eighth of an ounce of sand, which has been previously freed from its pulverulent particles by washing, and afterwards thoroughly dried, and pour the mixture into a glass vessel, with two ounces of strong alcohol. Tie a piece of bladder over the vessel, and let it remain for several days in a warm place, frequently stirring it round. The clear solution of resin thus obtained is called *lac-varnish*, because, when smeared over metal, wood, or paper, it leaves behind, after the alcohol has evaporated, a varnished, shining coat. If alcohol is poured upon the sandarach, unmixed with sand, the resinous powder will cake together on the bottom of the vessel, forming a tenacious mass of resin, which dissolves much more slowly. To *varnish*, then, is to smear the surface of any thing with resin. By this coat of varnish articles not only acquire a beautiful brilliancy, but are rendered at the same time impervious to air and water. When paper articles — for instance,

drawings, charts, &c. — are to receive a coat of varnish, glue or a solution of gum must previously be spread over them several times, as the solution of resin would otherwise penetrate into the fibres of the paper, and render it gray and transparent. This imbibition is usually prevented in wooden articles by smearing them with linseed oil before putting on the varnish. When the varnish is applied on places that are wet, white opaque spots are formed, because the resin is separated by the water as a dull white powder.

Experiment. — Dissolve half an ounce of shellac in strong alcohol; a turbid liquid is obtained, as the shellac contains, besides the resin, small quantities of wax and mucilaginous substances, which float about undissolved in the solution of resin. This solution is also employed as a lac varnish, but much more frequently as the so-called *polish* of the cabinet-makers; that is, as a solution of resin, which they rub continuously upon the wood with a ball of linen, until the alcohol has evaporated. By this means a yet smoother and finer polish is obtained than by merely applying the resinous solution with a brush, the marks of which frequently remain visible. The finer articles of furniture are usually polished, the more ordinary ones varnished.

579. *Resins and Oils.* — *Experiment.* — Mix half an ounce of dammara resin with some sand, and pour over the mixture two ounces of oil of turpentine; after a few days you will obtain an almost complete solution, *as the volatile oils are likewise able to dissolve resins.* These solutions are also frequently employed as lac varnishes; they dry, indeed, more slowly, but form a more tenacious coating, which is less liable to crack. The paler and finer varieties of varnish are principally *prepared from* amber, copal, dammara, shellac, sanda-

rach, and mastic; the inferior and darker kinds, from amber-colophony, common colophony, turpentine, asphaltum, &c. A yellow color is sometimes given to the pale varnishes by the addition of dragon's-blood, or gamboge.

The resins are likewise soluble in *fat oils*. Many ointments and plasters of the apothecaries consist of mixtures of fats and resins, and it is the latter which communicate to the former the property of adhering to the skin. Turpentine is usually employed for this purpose.

580. *Resinous Soap.* — *Experiment.* — Boil in a jug a quarter of an ounce of rosin, with one ounce of strong potassa or soda lye, and then gradually add lye by spoonfuls, until a sample of the mixture dissolves in hot water, forming a clear liquid. The mass hardens, on cooling, into a solid *soap* (a compound of the resinous acid and potassa, or soda). The resins, as we see, comport themselves towards strong bases like the fat acids, and hence have an extensive application in the manufacture of soap, being mixed with the fats in different proportions in the manufacture of the cheaper kinds of soap.

Experiment. — Mix a solution of resin soap with a solution of alum; an insoluble combination of *resinous acid and alumina* is formed. Resin soap is employed for the sizing of paper; it is first introduced into the vat containing the pulpy mass of which the paper is to be made, and then the solution of alum is added. There is thus formed round each fibre of the paper a thin layer of insoluble alumina soap (resinous acid and alumina), which prevents the spreading of the ink. According to the old method, the sheets of paper were passed through a solution of glue, whereby only a thin layer of glue was formed on the surface of the paper. This kind of paper allows the ink to spread, when the coat of glue has been scraped off by erasure; but this may be prevented by rubbing some resin — sandarach is the best — upon the spots erased.

Resins combine with bases, and their solutions redden litmus-paper. Accordingly, they may be regarded as *acids*.

581. *Composition of the Resins.* — By alternate treatment of the resins with cold or hot, weak or strong alcohol, or with ether, various kinds of resin may be extracted from most of them, which have been designated by the terms alpha (α), beta (β), or gamma (γ) resins. The natural resins are accordingly to be regarded as mixtures of several simple resins.

Only the three elements carbon, hydrogen, and oxygen (C, H, O) occur in the resins. That they contain somewhat more oxygen, and less hydrogen, than the volatile oils, has already been stated (§ 566); but, nevertheless, they belong to the *bodies rich in hydrogen*, since they burn with a strong flame.

GUM-RESINS.

582. If you divide a stem of poppy, lettuce, or celandine, a white or yellow juice exudes, which dries up in the air or by the heat of the sun, forming a yellow or brown amorphous mass. This milky juice consists of a solution of gum, intimately mixed with minute drops of resin; thus it forms a natural emulsion. This kind of dried, half-resinous, half-gummy vegetable juice is called, from these two proximate constituents, *gum-resin.* Many plants of hot climates are especially rich in such resins, and from them are principally obtained the gum-

resins occurring in commerce, which have various applications, particularly in pharmacy. Among the most important are, —

Ammoniac (*gum ammoniac*), the inspissated milky juice of an African umbelliferous plant; it has a yellowish or brown color, and a strong, peculiar smell and taste.

Assafœtida (*stercus diaboli*), the juice of a Persian umbelliferous plant, having a very unpleasant smell, like that of garlic; it has a milk-white appearance when freshly broken, but quickly changes in the air and light into a pink color.

Aloes, which has a brown or black color, and is exceedingly bitter; it is the dried juice of the aloe-plant, which grows in great abundance on the Cape of Good Hope and the adjacent islands.

Euphorbium, which comes in brownish-yellow tears from the African plant Euphorbia Canariensis, and contains a very acrid substance, in consequence of which it vesicates the skin, and, when snuffed, excites inflammation of the nostrils and the most violent sneezing.

Galbanum, a yellowish or brownish substance, having a strong and peculiar odor; it is obtained from an evergreen plant of Persia.

Gamboge, which occurs in orange-colored masses or sticks; it is obtained from the leaves of an East Indian plant, and is principally used as a yellow water-color in painting.

Myrrh; the better sorts occur in pale, brownish-yellow fragments, the inferior sorts in dark brownish-red pieces; it has a bitter taste and a balsamic odor, and exudes from incisions made in a tree growing in Arabia.

Frankincense (*olibanum*), which comes in yellowish-white, brittle, roundish fragments; the juice, inspissated in the air, is obtained from a tree in Persia. It yields an agreeable odor upon glowing coals, and hence is much used for fumigating purposes.

Opium, a milky juice, which exudes from incisions made in the heads of unripe poppies, and is inspissated by exposure to the air; it occurs in large lumps of a dark brown color, having a bitter taste and an offensive narcotic odor. The soporific effects of it are well known.

Lactucarium, of a brown color, and having somewhat the odor of opium; it is the inspissated juice of several kinds of lettuce.

Opoponax, *Sagapenum*, *Scammony*, and many others.

PROPERTIES OF THE GUM-RESINS.

583. *Experiment.* — Triturate some one of the gum-resins with *water;* the gum is hereby dissolved, and a turbid, milky liquid (emulsion) is obtained. If this is boiled for some time, the softened particles of resin cake together, and separate as lumps; the liquid, having become clear, contains now only the gum in solution.

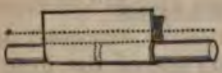
Experiment. — If strong *alcohol* is poured over the gum-resins, and they are digested together for some time, the resin only is dissolved, while the gum remains undissolved. The well-known tincture of myrrh is a solution in alcohol of the resinous particles contained in the myrrh. Most of the gum-resins contain, besides resin and gum, a small quantity also of volatile oils, to which they owe their peculiar *odor.*

CAOUTCHOUC (GUM ELASTIC).

584. There exudes from several large South American trees, when incisions are made in them through

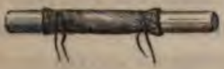
the outer and inner bark, a milky juice, which dries in the air into a white elastic mass, quite insoluble in water and alcohol. It is gum elastic, or caoutchouc. The drying proceeds more rapidly when the milky juice is spread upon moulds of clay or lime, and then suspended over a fire. If, after the gum is dry, the clay or lime is removed by washing, hollow articles of caoutchouc are obtained, but which have a black or sooty appearance on account of the soot mixed with them.

Fig. 214.



Experiment. — Caoutchouc at the ordinary temperature is hard and stiff, but it becomes soft when it is put into hot water or in a warm oven. Cut from one of these caoutchouc bottles, softened by heat, a square piece, apply it evenly round the ends of two glass tubes, and then clip off with a pair of scissors the ends of the strip in the direction marked out in the annexed figure: the fresh surfaces of the caoutchouc adhere firmly to each other (but still more closely when they are pressed together with the nail, yet without touching the freshly cut surfaces), and thus is formed a tube, which, firmly tied at both ends, binds the two glass tubes air-tight with each other. In this manner, the glass tubes occurring in chemical apparatus are made pliant and flexible, and the risk of breaking them is thereby diminished.

Fig. 215.



Experiment. — Pour some petroleum upon a few pieces of caoutchouc; the caoutchouc will swell up in it, and may then be converted into a homogeneous mass. When melted with shellac, the mass affords a *very* permanent cement for wood, stone, and iron (*ship-glue*).

Experiment. — If ether, oil of turpentine, or oil of pit-coal tar is poured upon caoutchouc, a complete solution is obtained. Solutions of this kind are now frequently employed for rendering fabrics waterproof (*Mackintosh*). When strongly heated with alcohol, caoutchouc forms a homogeneous, tenacious, black mass, which is very well adapted for smearing shoe-leather.

Experiment. — When caoutchouc is held in a burning lamp, it takes fire and burns with a vivid, sooty flame, like petroleum or oil of turpentine, and melts into a black, glutinous residue. This melted caoutchouc is very serviceable for preventing the sticking of glass stoppers in bottles, in which lye, &c., is kept; the stoppers, when coated with it, remain lubricous for a long time.

Caoutchouc acquires an extremely high degree of elasticity by intimately mixing it with sulphur, or sulphuret of arsenic (*vulcanized caoutchouc*).

Caoutchouc is one of the few solid bodies which contain *no oxygen;* it consists only of carbon and hydrogen, so that it may be regarded, as it were, as condensed petroleum, or as condensed illuminating-gas.

Gutta Percha. — Under this name, within a short time, a substance resembling caoutchouc has occurred in commerce, which is procured from the milky juice of several East Indian trees; it has the advantage over caoutchouc, that it becomes quite soft and plastic by moderate heating, but hard again on cooling, and has found already various applications in the arts.

RETROSPECT OF THE FATS, VOLATILE OILS, AND RESINS.

1. The fats, volatile oils, and resins are among the very generally diffused substances of the vegetable kingdom; most of them comport themselves like indifferent bodies, many like feeble acids.

2. As occurring in nature, they are mixtures of several similar substances with each other, which are, —

a.) The fats; mixtures of solid fats (stearine, margarine) and of fluid fats (oleine, glycerine).

b.) The volatile oils; mixtures of solid stearoptene and fluid oleoptene.

c.) The resins; mixtures of several different kinds of resin (alpha, beta, gamma resins, &c.).

3. As respects their elementary constitution, they consist only of the three elementary substances, carbon, oxygen, and hydrogen; but they are always *poor in oxygen and rich in hydrogen.* (Some volatile oils contain no oxygen.)

4. On account of the excess of hydrogen, —

a.) They burn, when ignited, with a brisk flame, and yield, on decomposition by a glowing heat, much combustible gas.

b.) Most of them are so light that they float upon water.

c.) They are dissolved only in liquids which are likewise rich in hydrogen and poor in oxygen; for instance, in alcohol and ether, but not in water.

5. They are either liquid, or are easily rendered so, even when gently heated.

6. The *fats* of animals have exactly the same *constitution* as the vegetable fats.

7. By the addition of oxygen many kinds of fat be-

come solid and hard (varnish oils), others, on the contrary, become rancid without hardening (unctuous oils).

8. The fats are resolved, by strong inorganic bases, into peculiar acids insoluble in water (fat acids), and into an organic base (oxide of glyceryle). The separated fat acids hereby combine chemically with the inorganic bases, forming *soaps*. The alkalies form, with the fat acids, soaps which are soluble in water; the oxides of the earths and metals, on the contrary, form soaps which are insoluble in water.

9. The *volatile oils*, by the addition of oxygen, pass into resins; often also, at the same time, into acids.

10. The *resins* evince no great affinity for oxygen; at least they do not alter, however long they may be exposed to the air.

11. Many of the resins combine with the alkalies, forming soaps soluble in water; with the earths and metallic oxides, forming soaps insoluble in water (resinous soaps).

12. *Balsams* are mixtures of resins with volatile oils; *gum-resins* are mixtures of resins with gum.

XII. EXTRACTIVE MATTER.

585. *Extracts.* — The vegetable substances hitherto considered are, if we except the volatile oils and some resins, mostly without taste and without any striking medicinal effect; most of them occur very generally diffused in the vegetable kingdom, and are found in almost all vegetables. But we observe in many plants a *peculiar taste*, and when swallowed a peculiar effect

upon our bodies; consequently, there must be other special substances present, from which the taste and effect proceed. Wormwood and rhubarb have a bitter taste, pepper and henbane a pungent and sharp taste, the roots of couch-grass and of liquorice a sweet taste. When introduced into the stomach, wormwood is stomachic, rhubarb purgative, pepper stimulating, henbane narcotic, &c. These and similar actions must, even at an early period, have excited the attention of man, and led him to extract the tasting and medicinal principles from the plants, and to use them in medicine. This extraction was effected in a simple manner, from the juicy parts of the plants by expression; from the drier parts, by treating them with cold water (maceration), or with hot water (infusion), or by boiling them with water (decoction). As the vegetable juices or extracts would soon become sour or mouldy, the water is evaporated away; by this means, a pulpy or pasty mass, or, on more complete desiccation, a solid amorphous mass, is obtained, which is called an *extract* (watery extracts), and may be kept for years unchanged and undecomposed. Sometimes, instead of water, alcohol or ether is used as a solvent (alcoholic and ethereal extracts). Many of these extracts are always kept on hand by the apothecaries as medicines, and one ounce of them frequently contains as much active matter as one pound, or even several pounds, of the vegetable substance from which they were prepared.

It has already been stated, that most of the vegetable juices contain sometimes larger, sometimes smaller, quantities of starch (sediment), mucus, gum, sugar, tannin, chlorophyll, vegetable albumen, salts, acids, &c.; hence, all these substances do not volatilize on evaporation, but some of them must also be present in the watery extracts. It is likewise clear, that in the spirituous and ethereal extracts all those substances which can be dissolved from the vegetable substances acted upon by either alcohol or ether must be present; for example, resins, fats, &c. *The extracts may, accordingly, be regarded as mixtures of various kinds of vegetable matter*, as mixtures of known with unknown vegetable matter, of that having taste with that having no taste, of the active with the inert, of the colorless with the colored, &c.

586. *Extractive Matter.*— On closer examination of the vegetable juices or extracts, it has been found that after the known substances, such as starch, sugar, albumen, &c., have been removed from them, a brown or black uncrystallizable, soluble mass remains behind, which generally possesses in a greater degree the taste and the medicinal effect of the plant from which it has been extracted. This mass is called *extractive matter*, and is distinguished by the following and other properties: — *bitter* (in wormwood, buckbean, aloes, colocynth, &c.), *aromatic bitter* (in the root of the sweet-flag, in hops, &c.), *acrid* (in senega-root, soapwort, &c.), *sweet* (in liquorice-root, root of couch-grass, &c.), *narcotic* (in hemlock, henbane, &c.). The name was obviously a very convenient one, since it applied to all the innumerable vegetable substances not thoroughly examined, which possessed a dark color and did not crystallize, however different might be their chemical constitution. How great this difference may be we infer from this, that most vegetable substances, for instance, sugar and gum, when they are boiled for a long time, or merely exposed to the air, are converted into brown, uncrystallizable compounds.

587. The reason why all extracts have a brown or a black color is to be sought for in this ready changeableness of vegetable matter.

Experiment. — Pour upon some ounces of sliced liquorice-root six times the quantity of boiling water, and, after it has stood for some days, express the liquid; when this has been filtered through blotting-paper, it is clear, transparent, and of a sherry-wine color. Upon evaporation, we obtain from it a black extract, the well-known Spanish liquorice, which, when redissolved in water, no longer yields a yellowish, but a dark-brown liquid. Not only the color, but the taste also, has perceptibly changed. Both changes clearly show, that during the evaporation a chemical decomposition of the dissolved matter has taken place. It is very similar to that which happens during the putrefaction or slow oxidation of wood; namely, oxygen is absorbed from the air, and some hydrogen and carbon are hereby oxidized into water and carbonic acid, whereby substances similar to humus, richer in carbon, and consequently darker-colored, are formed. These are in part dissolved in the water, and cause the dark color of the liquid; but they are in part no longer soluble, and therefore separate from the solution as a dark-colored sediment. This sediment has been designated by the likewise very indefinite term, *oxidized extractive matter.* From this it results as a general rule in the preparation of extracts, that the evaporation of the vegetable juices should be conducted, if possible, with exclusion of air, and at a gentle heat; it is best done over the water-bath.

588. *Crystallizable Extractive Matter.* — In modern times, several of these peculiar substances have been obtained in a crystalline form, consequently as fixed and independent compounds. Many of these behave very

much like the inorganic bases (potassa, soda, ammonia, &c.); that is, they are able to neutralize acids and to form salts with them: *these are the organic bases* (§ 596). Others, on the contrary, possess neither basic nor acid properties, — they are *indifferent*, and may be called *crystallizable extractive substances*, at least until their chemical behaviour shall have been more accurately ascertained by further investigations. As yet, too little is known about them to enable us to express any decided opinion concerning them. The number of the plants now known exceeds a hundred thousand, and it is not improbable that extractive matter is to be found in most of them; consequently they present a fine field for new discoveries. After what has been said, we may include under the term *extractive matter* all sorts of chemical substances of indifferent crystallizable, and of indifferent brown, uncrystallizable matter, to which in most cases we ascribe the peculiar taste and the peculiar medicinal effects of plants. Most of them are characterized by a bitter taste, and hence are frequently called *bitter substances*. Some of them, namely, those which are insoluble in water, do not evince the taste peculiar to them until they are dissolved in some other liquid, for instance, in alcohol or ether.

589. The *best known of these peculiar substances* will now be briefly referred to. Their names (as also the names of coloring matters and of the organic bases) are usually formed from the Latin names of the plants, with the addition of the affix *in* or *ine*.

Absinthine, from wormwood, very bitter; a colorless crystalline mass.

Amygdaline, from the bitter almonds, slightly bitter, crystallizes in lustrous silky scales; it has the very remarkable property of being converted into a volatile oil containing prussic acid (oil of bitter almonds) when it is mixed with dissolved vegetable albumen.

Centaurine, from the Chironia centaurium, bitter; as yet only known as an extract.

Cetrarine, from Iceland moss, bitter; a white powder.

Columbine, from columbo-root, very bitter, crystallizes in white prisms.

Gentianine, from gentian-root, very bitter, crystallizes in yellow needles.

Imperatorine, from masterwort, very acrid and burning; in white crystals.

Lupuline, from hops, an agreeable bitter; a white or yellowish powder.

Meconine, from opium (poppy-juice), acrid to the taste; in white crystals.

Picrotoxine, from the seeds of the Cocculus Indicus, very bitter, narcotic, and poisonous; in white needles.

Quassine, from the wood of the quassia, very bitter; in white crystals.

Santonine, from worm-seed, bitter, in white crystals.

Scillitine, from squill, nauseously bitter; a white amorphous mass.

Senegine, from senega-root, acrid and astringent; a white powder.

Glycyrrhizine, from liquorice-root, very sweet; a pale-brown amorphous mass.

Populine, from the leaves and bark of the poplar, sweet; crystallizable in white needles.

Asparagine, from asparagus, having an insipid taste; in white crystals.

Smilacine, from the root of the sarsaparilla, tasteless; in white crystals.

By far the greater proportion of these substances consist of the three elements *carbon*, *hydrogen*, and *oxygen;* some few only contain also a little nitrogen.

XIII. COLORING MATTER, OR PIGMENTS.

590. When the peculiar substances which have been treated of in the previous section, under the name of extractive matters, are themselves colored, or become so by the action of other substances, they are called *coloring matter*, or *pigments.* Most of those colors whose inimitable splendor and variety we admire in the flowers of plants are so exceedingly evanescent, that they fade or disappear on withering or drying, and very rapidly, especially when they are exposed at the same time to the sunshine. The same happens when we attempt to extract or separate the coloring matter by expression, or in some other way. A few plants only contain, sometimes in the roots or the wood, sometimes in the leaves or fruit, coloring juices of such permanency that they are more difficultly and slowly decomposed by the light; these may be extracted, and then employed for coloring other substances. These colors, however, are turned white by chlorine or sulphurous acid (bleached). Their extraction may be effected in most cases by water, sometimes also by alcohol or other liquids. As some extractive substances in the former section have been obtained in a crystalline form, so also crystallized coloring substances have been separated from colored extractive matter; but other coloring principles, on the contrary, are only known in the form of extracts. The names which have been given to these coloring sub-

stances likewise terminate in *ine*, and are included in parentheses in the following list of the most important vegetable coloring matters.

591. *Red and Violet Coloring Substances.*

a.) *Madder* is the ground-up root of the Rubia tinctorum. The fresh root looks yellow, but when exposed to the air it becomes red, owing to the absorption of oxygen, and yields a superior permanent or fast red color in dyeing, for instance, the brilliant Turkey-red; also beautiful varnish colors, such as madder-varnish. (Coloring matter, *Alizarine*, or madder-red, crystallizes in yellowish-red needles, soluble in boiling water.) Madder contains, moreover, a yellow, an orange, and a brown coloring matter.

b.) *Brazil-wood* (Fernambuca), from the heart-wood of several trees growing in South America, imparts to different materials a beautiful but not very permanent (not fast) red color. It is employed also in the preparation of red ink, of drop-lake, &c. (Coloring matter, *Braziline*, crystallizes in orange-colored needles, easily soluble in water.)

c.) *Safflower*, the flowers of the dyer's saffron, are used for obtaining a brilliant rose-color (for pink-saucers). (Coloring matter, *Carthamine*, soluble in water.)

d.) The *alkanet-root* contains in its bark a resinous coloring matter, which is consequently not soluble in water; cloth is dyed violet with it, but alcohol, oils (as petroleum), and fats (as lip-salve), are colored pink with it.

e.) *Sandal-wood* (red sanders-wood), the rasped blood-red wood of a tree growing in the East Indies, contains likewise a red, resinous coloring matter (*Santaline*).

f.) The red pigments occurring in many *fruits*, as, for instance, cherries, raspberries, &c., are but slightly durable, and only used for coloring confectionery, cordials, &c.

g.) *Cochineal* is a dried insect, which is brought to us from Mexico. The well-known red carmine is obtained from it, and in dyeing establishments a very brilliant scarlet and purple red is prepared from it. (*Cochineal-red*, reddish-purple, crystalline grains.)

h.) *Lac-lake*, or *lac-dye*, is a reddish-black, resinous mass, which is obtained in the preparation of shellac (§ 570); it contains a red coloring matter very similar to cochineal-red.

592. *Yellow Coloring Substances.*

a.) *Fustic* is the rasped trunk-wood of a mulberry-tree growing in the West Indies. (*Morine*, crystallizes in yellow needles, soluble in water.)

b.) *Quercitron*, a nankeen-yellow powder, mixed with fibrous fragments, is obtained from the bark of the black oak, a tree of North America. (*Quercitrine*, a yellow powder, soluble in water.)

c.) *Buckthorn*, *Persian*, or *French berries* are the fruit of the buckthorn, growing in warm countries, and gathered before they are ripe. (Coloring matter only known as an extract, soluble in water.)

d.) *Weld* and *dyer's weed* are the names given to the Reseda luteola, dried after it has done blooming. (*Luteoline*, crystallizes in yellow needles, soluble in water.)

The four last-mentioned coloring substances are principally used for dyeing silk, wool, cotton, and other materials, yellow.

e.) *Annotto, orleana*, occurs as a brownish-red paste, which is prepared from the pulp surrounding the seeds of the Bixa Orellana, and contains two coloring principles, a yellow and a red. The former is dissolved when the annotto is boiled with water, the latter on boiling it with a weak lye (*Orelline*).

f.) *Turmeric*, the root of a plant growing in the East Indies, is very rich in a resinous yellow pigment, which is colored brownish-red by alkalies. Paper stained with it may therefore be used like red litmus-paper for detecting alkalies. (*Curcumine*, an amorphous yellow mass.)

g.) *Saffron* consists of the dried stigmas of the flowers of the Crocus sativus. Its application, in coloring articles of food and cordials yellow, is well enough known. (*Polychroite.*)

593. *Green Coloring Substances.*

Leaf-green (*chlorophyll*) is one of the most widely diffused substances in the vegetable kingdom, since it occurs in all parts of the plant which possess a green color. As found in plants, it is a mixture of wax and of several coloring matters not well known. It need hardly be said, that it is not soluble in water; for if it were, the water would become green on flowing over meadows. The expressed juices of the herbs are indeed green, but it is obvious from their turbidness that the leaf-green is only mechanically mixed with the liquid. We become still more fully convinced of this by the separation of the coloring matter which takes place when the juices are boiled, or allowed to remain for some time in repose. If, on the other hand, alcohol, ether, or weak lye, is poured on the green leaves, we obtain green solutions; hence all the tinctures of pharmacy which are prepared from leaves or stalks have a green color. The green color appears only in those parts of the plant which are exposed to the light; it is obvious from this, that the chemical compound which we call chlorophyll is only generated with the coöperation of light. When separated from plants, this coloring matter is very soon decomposed; it is, therefore, not at all suited for a coloring substance, except, perhaps, for cordials and other liquids. In the autumn it is converted in the leaves themselves into leaf-yellow and leaf-red, probably by a process of oxidation.

Sap-green is an extract prepared from the juice of the buckthorn berries, by the addition of alum.

594. *Blue Coloring Substances.*

Indigo. — Several plants of hot climates contain a colorless juice, from which, after standing in the air and abstracting oxygen from it, a blue sediment is deposited, that, when dried, forms the well-known indigo. This substance, very important to science and the arts, usually occurs in commerce in deep blue, friable cakes, which exhibit, when rubbed by the nail, a coppery color and lustre. Its brilliant blue coloring matter is called *indigo-blue;* but besides this, the crude indigo contains other foreign substances, such as indigo-gluten, indigo-brown, indigo-red.

Indigo is quite insoluble in water, alcohol, ether, &c.; there is only one liquid known which can dissolve it, fuming sulphuric acid (§ 170). The indigo-blue chemically combines with the sulphuric acid, forming a blue compound soluble in water, which is called *sulphindigotic acid.* What we call tincture of indigo is principally a mixture of water, sulphindigotic acid, and free sulphuric acid.

The sulphindigotic acid combines like a simple acid with bases, forming salts. The best known of these salts is *sulphindigotate of potassa* (blue carmine), which is obtained as a deep blue precipitate when the sulphindigotic acid is neutralized by potassa. The blue carmine is indeed soluble in pure water, but not in water containing a salt in solution.

Deoxidation of Indigo. — We can also, but in a very different way, render indigo soluble, by mixing it with bodies which have a very great affinity for oxygen; for instance, with protoxide of iron, protoxide of tin, &c.

Experiment. — Triturate half a dram of finely powdered indigo, with half a dram of green vitriol, and one dram and a half of slaked lime; shake up the mixture in a four-ounce bottle; then, having filled the bottle with water and closed it tightly, let it stand for several days; the indigo gradually loses its blue color, and dissolves into a clear yellowish liquid. The body which effects the decoloration is the protoxide of iron, which is separated by means of the lime from the green vitriol. This attracts oxygen from the indigo, whereby the latter becomes colorless and soluble in lime-water (*reduced indigo*). As soon as the clear liquid is exposed to the air, it again attracts oxygen and becomes blue. If you saturate a piece of blotting-paper with the liquid, and then dry it in the air, it first becomes green, and then blue, and the blue color formed adheres quite firmly, since it has not only settled *upon* but *in* the fibres of the paper. In dyeing establishments, such a solution of indigo is called the *cold vat.* Another method of rendering indigo soluble is by adding it, together with hot water, to a mixture of bran, woad, madder, &c., which (carbonate of potassa and lime being present) passes into fermentation. The fermentation is partly acid, and partly putrid; in both processes oxygen is required, which is in part taken from the indigo. The deoxidized, colorless indigo dissolves in the alkaline liquid (*warm vat*). By treating indigo with bodies which readily part with oxygen, for instance, with nitric acid, chromic acid, &c., we have in modern times become acquainted with some very interesting products of oxidation (isatine, isatinic acid, anilic acid, picric acid, &c.).

Woad is a European plant, which likewise contains indigo, but in far less quantities than the foreign indigo plants.

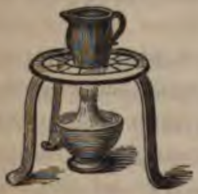
Logwood, or *Campeachy-wood*, the reddish-brown interior wood of a tree of tropical America, is one of the most common coloring matters for dyeing blue, violet, and black. (*Hæmatoxyline*, in yellowish crystals, which become speedily violet and blue in the air, owing to the ammonia always contained in the latter.)

Archil. — Several species of lichens, growing on the rocks in England and France, contain peculiar substances (*orcine*, *erythrine*, &c.), which, although in themselves colorless, acquire a beautiful purple-red color when they are acted upon by ammonia. It is common to putrefy the bruised lichens with urine, and then a red or violet-colored paste is obtained (*cudbear*, *persio*, *orchil*). By the addition of lime or potassa, this red is changed into blue (*litmus*). We have examples of both these coloring matters in red and blue test-paper.

595. *Experiments with Coloring Substances.*

Experiment a. — Take up some sandal-wood on the point of a knife and put it on a filter, and pour over it some alcohol; the alcohol which passes through has a red color, and, when poured upon a piece of wood, imparts to it an intense blood-red color. Cabinet-makers frequently employ this solution for staining furniture. Alcohol acquires a pink color when a small piece of *alkanet-root* is put into it. Water will not extract a red pigment from either of these substances. Those coloring matters which are soluble only in alcohol are called *resinous.*

Fig. 216.



Experiment b. — Boil for some time in a jar, — 1st, *French berries;* 2d, *Brazil-wood;* and 3d, *logwood;* each separately, with twelve times its amount of water; the decanted decoction of the first is yellow, of the second reddish-yellow, and of the third brownish-red; a sufficient proof that the coloring matters contained in these substances have been dissolved in the water. Dyers call these colored decoctions *baths.*

Experiment c. — Divide these coloring decoctions into two equal parts. Dissolve a quarter of an ounce of alum in one of each of the parts, and then add to them a solution of carbonate of potassa, as long as any precipitate subsides. As was stated in § 260, the hydrate of alumina is precipitated; but, together with this, the coloring matter is also precipitated, and hence the precipitates are colored. These precipitates are called *lakes.* The lake obtained from the French berries occurs in commerce under the name of yellow lake, that from Brazil-wood as drop-lake.

Experiment d. — Prepare a solution of alum (*a*), another of salt of tin (*b*), a third of green vitriol (*c*), a fourth of carbonate of potassa (*d*), a fifth of tartaric acid (*e*), and saturate a sheet of white blotting-paper with each solution. When dry, cut each sheet into three strips, smear one of the strips from each sheet with the fustic, another of them with the Brazil-wood, and the third set with the logwood decoction, and again dry them. You will find that one and the same coloring matter produces a different color, or shade of color, upon each of the five sheets. This color will be very slight when the colored decoctions are applied to mere blotting-paper (*f*). If you now immerse the colored and dried strips in warm water, the colors will be for the most part dissolved from the three last tests (*d*, *e*, *f*), but not from the former (*a*, *b*, *c*). Those salts which, like alum, salt of tin, and green vitriol, have the power of forming insoluble combinations with the coloring matters, and fixing them firmly in the fibres of the cloth, are called *mordants*, and are generally employed in dyeing and calico-printing establishments, to fix the pigments upon the various materials, such as silk, wool, cotton, linen, &c. That which effects the coloring is an insoluble lake color, that is, a combination of the coloring matter with alumina, peroxide of tin, or sesquioxide of iron, but which, in order that it may adhere firmly, must first be formed *within* the pores of the vegetable fibre. If it is formed on the outside of them, it only covers the fibres externally, and then merely adheres mechanically *upon* them; such a color may be removed from the material by rubbing, shaking, and also by washing.

The process pursued in the *printing of calico*, &c., is very similar, with this difference, however, that the mordants are only applied *in spots*, or else the whole of the cloth is first covered with the mordant, which is again removed in spots (§ 197). When a piece of cloth thus treated is immersed in the coloring decoction, the coloring matter will be precipitated only in those places *covered with the* mordant, and thus, instead of one uninterrupted homogeneous color, an interrupted color is obtained, presenting a pattern.

XIV. ORGANIC BASES, OR VEGETABLE BASES (ALKALOIDS).

596. It has already been mentioned, under the head of extractive matter, that many plants contain peculiar substances, which, like the inorganic bases, can combine with acids, forming salts; they are called *organic bases.* Many of them, also, like the alkalies, exert a basic reaction upon *red test-paper;* hence the second name, *alkaloids.* The organic bases are to the inorganic bases what the organic acids are to the inorganic acids. The organic bases are composed of two, commonly of four elements (carbon, hydrogen, oxygen, and nitrogen), the inorganic of two elements only; they are charred and consumed by heat, — the inorganic bases are not; they undergo, in the presence of water and heat, a putrefactive decomposition, — the inorganic bases do not. They are characterized by containing, almost without exception, *nitrogen* in their composition.

Almost all organic bases dissolve with difficulty, or not at all, in water, but more readily in *alcohol;* their solutions have commonly a very *bitter* taste. As a general rule, they dissolve, when combined with acids as salts much more easily in water, than they do when in their simple condition.

Most of the organic bases known at present are derived from those plants which are characterized by their *poisonous* qualities or by their medicinal effects, and we have strong reasons for attributing to them the poi-

sonous and *medicinal properties* of the plants. Many of them are virulent and dangerous poisons; but in very small doses they are energetic medicines. One grain frequently possesses the same medicinal power as an ounce, or even several ounces, of the vegetable substances from which they were obtained.

The vegetable bases, when they are dissolved, are almost without exception precipitated by *tannic acid* as nearly or entirely insoluble tannates, for which reason liquids containing tannic acid, such as tincture of gall-nuts, decoction of green tea, or of oak-bark, &c., are not only employed as reagents for detecting vegetable bases, but also as efficient antidotes in cases of poisoning by them.

The vegetable bases occur generally in combination with vegetable acids. They are separated from these acids, and extracted from the vegetable matter, by adding to the latter some water, and an acid which is stronger than the vegetable acid and forms with the base an easily soluble salt (muriatic acid, sulphuric acid, &c.). If an inorganic base (potassa, lime, ammonia, magnesia, &c.) is added to the acid solution, the organic base is then precipitated. But there are also numerous other methods of preparing these bases; all of them, however, are long and complicated, for the reason that many other substances are also extracted from the plants at the same time with the bases, which, in very many cases, can be separated and purified only by laborious operations.

597. Some of the most important organic bases are: —

Aconitine, from the Aconitum napellus (monk's-hood), a white, *granular* powder, extremely poisonous; $\frac{1}{10}$ *of a grain will kill* a sparrow.

Atropine, from the root of the belladonna (deadly nightshade); it crystallizes in white silky prisms; very poisonous.

Chelidonine, from the celandine; crystallizes in colorless tables.

Quinine is found combined with kinic acid, chiefly in the crown-bark and in the Calisaya-bark, and crystallizes in silky needles; but it also occurs under the name of *quinoidine* in the amorphous state, as a dark-brown resinous mass, and is a very important medicine. The *basic sulphate of quinine*, which occurs in white needles, is most commonly used in medicine. This is very difficultly soluble in water, but is very readily dissolved in it when sufficient sulphuric acid is added to convert it into *neutral sulphate of quinine*. Another base, very similar to quinine, occurs in the gray cinchona-bark; it crystallizes in white prisms, and has received the name *cinchonine*.

Caffeine, or *theine*, from the unroasted coffee-bean, or the so-called green tea; crystallizes in fine white prisms of a silky lustre.

Colchicine, from meadow-saffron; crystallizes in white needles; it causes, when taken, the most violent vomiting.

Daturine, from the seeds of the thorn-apple, in colorless crystals; highly poisonous.

Emetine (from ipecacuanha) occurs when pure as a white powder, when impure as a brown extract; a powerful emetic.

Hyoscyamine, from henbane, in radiated groups of white needles; a narcotic poison.

The Alkaloid of Opium. About forty years ago the *first* vegetable base was discovered in opium, — the inspissated juice of the poppy, — and was called morphine.

It exists in opium combined with meconic acid, and crystallizes in colorless prisms; narcotic and poisonous; in small doses, a very valuable remedy. The acetate of morphine* is much used in medicine. By later investigations there have also been found in opium pseudo-morphine, narcotine, narceine, codeine, and thebaine.

Piperine, from white, black, and long pepper; in white crystalline needles.

Solanine, from several species of the solanum, particularly from the white sprouts of the potato; as a white powder, or in crystalline, colorless needles; a narcotic poison.

Strychnine, from the nux-vomica (the seeds of the Strychnos nux-vomica), and from the Indian arrow-poison; crystallizes in prisms or octahedrons; very poisonous. There is another base, *brucine*, occurring along with it.

Veratrine, from white hellebore, and the seeds of the sabadilla; a lustrous white powder, extremely poisonous; when introduced into the nostrils, it excites the most violent sneezing; $\frac{1}{16}$ of a grain will kill a cat.

The following are volatile and liquid: —

Conicine, from hemlock, principally from the seeds; a colorless oily liquid, of a nauseous, strong odor; very poisonous.

Nicotine, from the leaves of the tobacco, colorless, oily, having a smell like that of tobacco. Highly poisonous; one fourth of a drop will kill a rabbit.

Vegetable bases may also be artificially produced, for instance, —

Aniline, from indigo, or from pit-coal tar.

Sinammine, from mustard, &c.

---

* *In this country* the sulphate is most generally employed.

RETROSPECT OF THE EXTRACTIVE AND COLORING SUBSTANCES, AND OF THE VEGETABLE BASES.

1. Besides the generally diffused vegetable substances, there occur in almost every plant *peculiar principles*, upon which, in many cases, the effect, taste, and color, of these plants depend.

2. We find these peculiar principles mixed with various other substances in the inspissated vegetable juices, the so-called *extracts*.

3. Many of them are non-azotized, others azotized, and still others contain at the same time sulphur.

4. Those combinations which are indifferent, and have no prominent color, are called *extractive matter;* they are also called bitter-extractive, because they have, for the most part, a bitter taste.

5. *Coloring matter* is extractive matter which has an absolute inherent color, or is converted by the action of other bodies into colored combinations; it is quickly rendered colorless by chlorine, slowly by light and air (bleached).

6. Coloring matter presents a great affinity for some *bases*, especially for alumina, sesquioxide of iron, and peroxide of tin, and forms with them insoluble colored compounds (*lake-colors*); in dyeing and calico-printing these insoluble precipitates are produced in the fibres of the yarn or material.

7. The *vegetable bases* can, like potassa or soda, combine with acids, forming salts; many of them also exert an alkaline reaction; most of them are difficultly soluble in water, but easily soluble in alcohol.

8. The vegetable bases occur principally in those plants which are characterized by particular poisonous or medicinal qualities. Many of them are very violent poisons.

9. Almost all vegetable bases contain nitrogen.

XV. ORGANIC ACIDS.

598. THE organic acids are found much more frequently, and in greater abundance, than the organic bases, in the vegetable kingdom. Several of them occur uncombined, or as acid salts; hence the acid taste which we perceive in so many vegetable substances, especially in unripe fruits. They are frequently, also, completely neutralized by bases, or are insoluble, as in the resins, and in both these cases they are not recognized by the taste. Besides these acids occurring in nature, many also have been discovered, which may be artificially produced from other non-acid vegetable substances; thus, oxalic acid and formic acid are prepared from sugar, acetic acid from alcohol, the fat acids from fats, &c. The general properties of these acids have already been mentioned (§ 193, &c.); we shall here notice only those which are best known.

599. *Racemic acid* occurs in the juice of many grapes, and crystallizes like tartaric acid, to which it is very similar, in colorless, very acid-tasted prisms.

600. *Citric acid* exists in the juice of lemons, and also in that of currants, gooseberries, and many other fruits. By evaporating the juice of the lemon, we only obtain an acid brown extract, because all the other non-volatile constituents, as well as the citric acid, remain behind; but if the juice is neutralized with chalk, a difficultly soluble citrate of lime is precipitated, while the foreign substances remain for the most part in solution. We obtain from citrate of lime, by decomposition with diluted sulphuric acid, gypsum and a solution of citric acid, which yields on evaporation colorless *prismatic crystals*. A mixture of the pleasant acidu-

lous-tasting citric acid (or tartaric acid) with sugar is called *lemonade-powder*. By moderate heating, the citric acid passes into *aconitic acid*, an acid which also occurs native in monk's-hood.

601. *Malic acid* is obtained from sour apples, berries of the mountain-ash, and many other plants; it is very deliquescent, and therefore is difficult of crystallization. Malic, citric, and tartaric acids are found associated together in almost all acid fruits.

602. *Formic acid* occurs in ants, but may be artificially produced from almost all vegetable matters, when they are treated with bodies rich in oxygen; for instance, nitric acid, chromic acid, black oxide of manganese, or sulphuric acid. It is a volatile, colorless liquid, of a very acid taste, and a very pungent odor.

603. *Tannic acid* (tannin) is the general name given to that substance, of very frequent occurrence in plants, especially in the barks of trees, which imparts to them the well-known puckering and astringent taste. It is regarded as an acid, because it has an acid reaction, and can combine with bases. These acids are divided, according to the plants in which they occur, into quercitannic, mimotannic, &c. acids. The *quercitannic acid*, which is found most abundantly in nut-galls and in the bark of young oak-trees, is best known. In the pure state it forms a white or yellowish gum-like mass, which is very easily dissolved in water and alcohol. It forms the principal constituent in the tincture of nut-galls. There are two properties which especially characterize tannic acid, and have stamped it as an extremely important substance in the arts:—

a.) It yields, with salts of sesquioxide of iron, a *blue-black precipitate* of tannate of sesquioxide of iron (§ 285), and therefore is generally employed for dyeing all kinds of materials with a gray or black color, and for the preparation of ink, &c.

b.) It combines, moreover, with the skin of animals, forming a combination insoluble in water, and no longer subject to putrefaction, — *leather;* hence the name *tannin*, and hence the extensive application of the vegetable substances containing tannin (bark of the oak, pine, birch trees, &c.) in the tanner's trade.

604. If a solution of tannic acid remains for a long time exposed to the air, it will be converted into two new acids, *gallic* and *ellagic acids*. Consequently, both are to be found in tincture of nut-galls, and in ink, which have been kept for some length of time. Gallic acid crystallizes in white needles or prisms; its solution yields, like tannic acid, a blue-black precipitate with salts of sesquioxide of iron, but it does not tan the skins of animals.

605. *Substances containing Tannin.* — The following are the principal dye-stuffs and tanning substances which occur in commerce.

a.) *Nut-galls.* They are produced on oak-leaves by the puncture of an insect. The best come from Asia Minor, and consist nearly one half of tannic acid; inferior sorts are brought from Italy and Hungary. The gall-nuts formed on trees in Germany contain but little tannic acid.

b.) *Catechu*, the brown, dry extract of the Acacia catechu, is now very frequently used in dyeing and calico-printing establishments, for the production of a brown color; sometimes, also, for tanning skins.

c.) *Kino*, the brownish-black extract of a tree growing in the East Indies.

d.) *Sumach*, or *Rhus*, the bruised leaves of several *kinds of rhus;* very important in dyeing.

e.) *Divi-divi*, the seed capsules of an African plant.

f.) *Bablah*, the pods of a species of mimosa growing in the East Indies.

g.) *The rind of the pomegranate*, *rind of the walnut*, &c., &c.

606. The acids just mentioned, together with tartaric, oxalic, and acetic acids, previously treated of, are very widely diffused; but besides these there are many others, which are found only in particular plants or vegetable substances, or are artificially prepared from them; as, —

Succinic acid, in amber; white crystals, volatile in the heat; it is formed also by the oxidation of stearic acid.

Benzoic acid, in benzoin; white crystalline needles, volatile in the heat; it is formed also in many ethereal oils, when long kept. The bitter oil of almonds, on exposure to the air, is oxidized, and completely converted into crystallized benzoic acid.

Cinnamic acid, in old oil of cinnamon and in balsam of Peru; white crystals.

Caryophyllic acid, in the oil of cloves; an oily liquid.

Valerianic acid, in the root of valerian; an oily liquid of a pungent odor. May be prepared, also, from the fusel oil of potatoes.

Suberic acid is prepared by heating cork or fat acids with nitric acid.

Fumaric acid, in fumitory and in Iceland moss; it is formed also by heating malic acid.

Chelidonic acid, in celandine.

Meconic acid, in opium.

Kinic acid, in cinchona-bark.

Lactic acid, in whey, sour-krout, juices of flesh, &c.

Uric or *lithic acid*, in urine, &c.

XVI. INORGANIC CONSTITUENTS OF PLANTS (ASHES).

607. If we review the proximate constituents of plants treated of in the preceding section, it will be seen that they are composed either of three elements (C, H, O), or of four elements (C, H, O, N). We may accordingly regard the *organogens*, carbon, hydrogen, oxygen, and nitrogen, as the four main pillars of the vegetable world. Next to them, sulphur appears widely diffused in the vegetable kingdom, since it forms a constituent of the albuminous substance never failing in any plant. But the list of the chemical substances occurring in plants is not yet finished; for were it so, plants would be completely consumed by heat without any thing being left behind. But on the combustion of every plant a residue remains, which neither burns up nor volatilizes; consequently there must also be present, besides the combustible organic compounds, some incombustible inorganic substances. The latter are termed *ashes*.

608. The term *ashes* is just as indefinite as that of humus. *Humus* is the term generally applied to all those black or brown substances formed during the decay of organic matter; but by ashes are understood all the non-volatile and incombustible substances which remain behind after the incineration of organic matter. How very different these may be, both in quantity and quality, is obvious from even a superficial observation of the three best known kinds of ashes, those of wood, peat, and pit-coal. From a hundred pounds of wood we obtain only half a pound, or at most three pounds, of ashes; from a hundred pounds of pit-coal or peat, twenty or thirty pounds of ashes. Wood-ashes contain very

many parts soluble in water, pit-coal and peat-ashes very few parts; the former yields with water a powerful alkaline lye, the latter does not; the former always acts on our fields and meadows as an excellent manure, the latter only in a small degree. Great differences also appear when the ashes of other plants or parts of plants are compared with each other, as may be seen from the following table:—

		Yield	Of which are soluble in water about
100 lbs.	oak-wood	2 to 4 lbs. ashes;	$\frac{1}{3}$.
100 "	oak-bark	5 " 6 " "	$\frac{1}{12}$.
100 "	oak-leaves (in spring)	5 " "	$\frac{1}{2}$.
100 "	" (in fall)	$5\frac{1}{2}$ " "	$\frac{1}{6}$.
100 "	dried potatoes	8 " 9 " "	$\frac{4}{5}$.
100 "	potato-tops	15 " "	$\frac{1}{15}$ to $\frac{1}{25}$.
100 "	wheat-grain	2 " 3 " "	$\frac{1}{2}$.
100 "	wheat-straw	4 " 6 " "	$\frac{1}{8}$ to $\frac{1}{10}$.

The quantity, as well as the nature, of the inorganic matter in plants consequently varies in the most remarkable manner, and not only according to the *difference of the plants*, but according to *the difference of the individual* parts of one and the same plant; indeed, even in the latter according to the *difference* of age. We always find the largest quantities of it in the younger vegetable organs, where the progress of growth is most active, namely, in the leaves and twigs.

609. If we ask what is the *constitution of vegetable ashes*, chemical analysis replies, that they consist principally of *potassa*, *soda*, *lime*, *magnesia*, and *sesquioxide of iron*, combined with *carbonic acid*, *silicic acid*, *phosphoric acid*, *sulphuric acid*, and *muriatic acid* (chlorine). Of these combinations there are principally,—

a.) Soluble in water, *the alkaline salts* (salts of potassa and soda).

b.) Soluble in diluted muriatic acid, *the earthy salts* (salts of lime, of magnesia, and of sesquioxide of iron).

c.) Insoluble in water and acids, *the silicates.*

The character of the prevailing inorganic constituents of a plant may be ascertained, though only in an approximative manner, by merely treating the ashes first with water, and then with diluted muriatic acid.

610. The above-named inorganic substances are often contained in the living plants in quite a different form from that in the ashes; namely, sulphur as a constituent of the albuminous matter, but the bases mostly as vegetable acid salts. That the latter are converted on ignition into carbonates (carbonate of potassa, of soda, of lime, &c.) has previously been shown under the heads of tartrate and oxalate of potassa (§§ 194, 197), and thus is explained why almost all ashes effervesce with acids. The sulphur, on the incineration of the plant, is partly converted into sulphurous acid, which escapes, and partly into sulphuric acid, which unites with one of the bases present, and remains behind in the ashes.

611. It has already been mentioned under the heads of phosphoric and silicic acids (§§ 176, 183), and of potassa and lime (§§ 214, 240), that these substances are able to exercise a very favorable influence upon the growth of plants, and that many plants will not flourish in a soil in which salts of potassa are wanting, and that others will not thrive in a soil which contains no lime, or no silicates or phosphates. The occurrence of inorganic substances in *all* plants must lead to the conclusion, that every plant requires a certain quantity *of them for its existence*, and for its complete develop-

ment. If the plant does not find them in the soil assigned to it, it is obstructed in its growth; it pines and withers away before attaining maturity. It is highly probable that basic bodies, as lime and potassa, act here in a predisposing manner, similar to that in the formation of nitric acid; that they effect by their presence the formation of organic acids, with which they afterwards enter into combination. On the further growth and ripening of the plants, there are formed, as it appears, from these acids, the indifferent substances starch, sugar, gum, &c.; for, as is well known, the acid taste is lost in many vegetable parts, especially in the fruits at the time of ripening, while a mealy, sweet, or mucilaginous taste supplies its place.

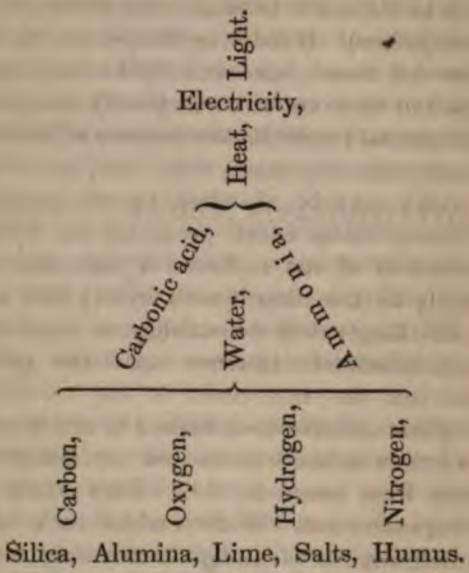
It follows from what has previously been stated, that the inorganic salts requisite for the growth of each individual plant may be ascertained most simply by burning the plant, and examining the ashes which remain; *it requires the same substances which are found in its ashes.* If we now examine the soil on which plants of this kind are to be cultivated, we shall find by comparison which of the constituents of the ashes are already present in it, and what constituents must be added to it that the plants may find therein all the mineral substances requisite for their development and growth.

612. *Arable land*, or *arable soil*, that is, the upper thin layer of the surface of our earth, in which plants germinate and take root, consists chiefly of two different kinds of matter; namely, *inorganic* substances, belonging to the mineral kingdom (silica, combinations of silicic, phosphoric, carbonic, and sulphuric acids with alumina, lime, magnesia, potassa, soda, and iron), and *organic* substances, derived from the animal and vegetable kingdom (humus-like substances).

The ground and soil which are adapted to vegetation are principally formed of *mineral substances*, more or less finely divided, which consist of rocks that have been disintegrated by the operation of the atmosphere, or weathered, during the lapse of centuries (§ 265). This weathering is going on uninterruptedly, even now, in the soil of the earth, and so much the more rapidly in proportion as the soil is loosened and penetrated by air and water (fallow). But during this process, the masses of rock are not merely mechanically broken into small fragments, but they are also chemically changed, since from their several insoluble constituents soluble salts — for instance, salts of potassa, soda, lime, &c. — are generated, which may be absorbed by the roots of the plants. Every thing which promotes the weathering and dissolution of the rocks — for instance, burning of the soil (§ 258), mixing it with lime (§ 240) or acids (§§ 173, 186, &c.) — will accordingly, as a general rule, exercise a beneficial influence upon the growth of plants.

The *organic substances* contained in arable soil have always a brown or black color, and are designated by the general term *humus* (§ 444). They partly consist of decaying leaves and branches, which have fallen off, and of decaying roots of plants remaining behind in the earth, and partly of decomposing vegetable or animal manure put upon the soil. It has already been previously mentioned, that these products of decay are gradually still further decomposed into carbonic acid, ammonia, and water, and for this reason cause a more vigorous growth of the plant. They likewise act favorably on vegetation, because by reason of their dark color the soil is heated more strongly by the rays of the sun, because they loosen the soil, and finally, because the weathering of the rocks is promoted by the carbonic acid which is set free from them.

XVII. NOURISHMENT AND GROWTH OF PLANTS.



613. *Carbon*, *oxygen*, *hydrogen*, and *nitrogen*,— these are the four elements which the Divine Power has established as main pillars for the structure of the whole organic creation; from them, and also from *sulphur*, *phosphorus*, and some other inorganic substances, all the numberless wonderful forms of the animal and vegetable world are produced. We as yet know but little about the interior chemical workings by which

these results are effected, but we have nearly ascertained the external conditions under which they take place, and the sources from which the above-named elementary substances are taken.

That plants require for their germination and development *soil*, *water*, *air*, *warmth*, and *light* — those universal conditions of vegetable life — is well enough known; while the chemical investigations of modern times, and particularly those instituted by Liebig, have first diffused a clearer light as to what single constituents are taken up from the earth, the water, and the air by the plants, and serve them as means of nourishment.

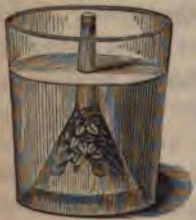
UNCULTIVATED PLANTS (MEADOWS, FORESTS, &c.).

614. *Food of Plants.* — Plants absorb their nourishment partly by the roots, partly by the leaves. It follows from this, that the nourishment must either be liquid or aeriform; for in these two forms only can it penetrate into the fine pores of the root-fibres and leaves. Plants receive their hydrogen and oxygen from the *water*, their carbon from *carbonic acid*, their nitrogen principally from *ammonia*, their inorganic constituents chiefly from the *earth*. Water, carbonic acid, ammonia, and a small number of inorganic salts, are accordingly to be regarded as the nourishment of plants.

a.) Water furnishes the plants with oxygen and hydrogen. — The plants imbibe it as a liquid, by their roots, from the earth, and as vapor, through their leaves, from the air. Water is moreover essential to plants, in so far as it occasions, by its fluid condition, the formation of the solid vegetable parts; for all the solid ingredients of the plants are developed from the juice, rendered liquid by water.

b.) *Carbonic acid furnishes the plants with carbon.* — This is *principally* absorbed (§ 167) by the leaves from the air, which is constantly supplied with it by the processes of combustion, decay, and respiration. Moreover, the roots of the plants find carbonic acid in every soil which contains humus, for humus consists of decaying organic matter, that is, organic matter resolving itself into carbonic acid and water (§ 444). From this limited source the young plants especially draw their nourishment, before they have leaves enough by means of which to appropriate to themselves the carbonic acid from the free air. The changes which the latter undergoes by the action of living plants are shown in the following experiments: —

Fig. 217.



Experiment. — Fill a glass funnel with the fresh leaves of some plant, and invert it in a wide glass vessel filled with water, in such a manner as quite to cover the funnel with water. Now close the upper opening of the funnel with a cork, suck out, by means of a glass tube, a part of the exterior water, and expose the vessel to the sun; bubbles of air will soon rise from the leaves, and collect in the tube of the funnel. When the water is so far pressed down within the funnel that it stands on a level with the exterior water, then uncork the funnel, and hold a glowing shaving in the gas evolved from the leaves; the shaving will inflame briskly, just as it would in oxygen gas. Indeed, this gas is really oxygen, which is derived from the carbonic acid contained in the water. Thus, in the *plants*, the carbonic acid has been resolved into its *constituent* parts, by the influence of light; its oxygen becomes free, and escapes, but its carbon remains behind in the plants. *The plants inhale carbonic acid, and in the light exhale oxygen.*

Experiment. — Repeat the experiment, but with this alteration, — pour, instead of common water, Selters water over the leaves; this contains a greater abundance of carbonic acid, and the consequence is, that the evolution of oxygen gas proceeds more briskly, and continues longer.

The principal mass of plants consists of vegetable tissue, starch, gum, mucus, sugar, &c., each composed of three elements; all these may be produced from carbonic acid ($C\,O_2$) and water ($H\,O$), when the elements of the water combine with the carbon of the carbonic acid. If this happens, the oxygen of the latter must necessarily be liberated. From

$$
\begin{array}{lll}
\text{Carbonic acid} & = & \qquad\qquad\qquad\quad \text{Carbon,} \quad \text{Oxygen,}\\
\text{and Water} & = & \text{Hydrogen, Oxygen,}\\
\text{are formed} & & \underbrace{\text{Hydrogen, Oxygen, Carbon}}_{\text{Vegetable tissue, starch, mucus, sugar, \&c.}} + \underset{\text{(is liberated).}}{\text{Oxygen}}
\end{array}
$$

It is also, perhaps, possible that the elements of the carbonic acid combine with the hydrogen of the water, and that accordingly the oxygen which becomes free is derived from the water; the chemical process would then be different from that just stated, but the results would be exactly the same. From

$$
\begin{array}{lll}
\text{Water,} & = & \qquad\qquad\qquad\quad \text{Hydrogen,} \quad \text{Oxygen,}\\
\text{and Carbonic acid} & = & \text{Carbon, Oxygen,}\\
\text{are formed} & & \underbrace{\text{Carbon, Oxygen, Hydrogen}}_{\text{Vegetable tissue, starch, mucus, sugar, \&c.}} + \underset{\text{(is liberated).}}{\text{Oxygen}}
\end{array}
$$

c.) Ammonia furnishes plants with nitrogen. — When vegetable and animal matters decay, ammonia ($N\,H_3$)

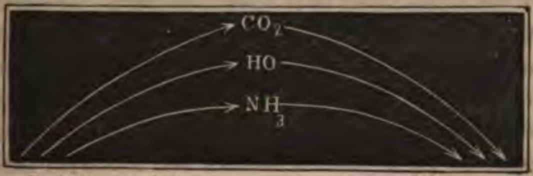
is formed from their nitrogen, carbonic acid from their carbon; both of these products combine with each other, forming a volatile salt which escapes in the air. It is condensed again from the air, partly by the loam or clay (§ 256) and the humus of the soil (§ 444), partly by the dew, rain, and snow, and returned again to the earth, and then with the water absorbed by the plants. If organic substances decay in the soil where plants are growing, the ammoniacal salt is, immediately after its formation, absorbed by their roots. Whether ammonia can be formed *directly* from the nitrogen of the air, where the latter is in contact with decaying substances in the moist earth, and can be of service to the plants, has not yet been ascertained with certainty.

In what manner the assimilation of ammonia takes place in the vegetable kingdom is, indeed, not yet known, but it is probably the ammonia from which plants take the nitrogen requisite for the formation of their azotized constituents, such as albumen, gluten, caseine, organic bases, &c. From

$$\begin{array}{lll} \text{Carbonic acid} & = & \text{Carbon, Oxygen,} \\ \text{Water} & = & \text{Hydrogen, Oxygen,} \\ \text{Ammonia} & = & \text{Nitrogen, Hydrogen,} \\ \text{are formed} & & \underbrace{\text{Nitrogen, Hydrogen, Oxygen, Carbon}}_{\text{Albumen, gluten, caseine, organic bases, \&c.}} + \underset{\text{(is liberated).}}{\text{Oxygen}} \end{array}$$

Carbonic acid, water, and ammonia accordingly contain in their elements the essential constituents for the formation of all vegetable substances (carbon, hydrogen, oxygen, and nitrogen). On decay and putrefaction, animal and vegetable matter is decomposed into carbonic acid, water, and ammonia. What seems *to us to* be annihilation is, however, only decay; the *form* only passes away, the matter itself is unchangeable. From the disgusting substances of decay are formed again the living wonders of the vegetable world.

Fig. 218.



d.) Plants are furnished, through the soil and water, with the requisite inorganic matters. — Our arable land is constantly undergoing changes; the organic matter contained in it decays, the inorganic is decomposed by the action of time and weather. By the last process soluble salts are always forming from insoluble rocks, which salts may now be absorbed by the roots of plants. Weathering takes place also beneath the surface of the earth, and indeed wherever air and water can penetrate into the mass of rocks. The substances thus rendered soluble are taken up by the rain-water, and constitute the salts contained in our common spring and river waters; accordingly, in many places plants can receive from water also inorganic matter. Finally, the air likewise contains inorganic substances which have been conveyed into it by evaporation (§ 182), especially from the ocean, and also by the force of the winds, and which are diffused by it over the whole earth. These are returned again to the earth in rain, dew, snow, &c., and thus we can no longer wonder at finding in plants salts (for instance, common salt) not existing in the rocks from which the soil serving as a habitation for these plants has been formed. The changes which these substances undergo in living plants have already been noticed in the preceding section.

It should still be expressly stated, that a plant can grow vigorously, thrive, and attain complete maturity, only when the substances mentioned at *a*, *b*, *c*, and *d* are *all four* presented to it *simultaneously*. As the life of man ceases if only a single condition necessary for his continued existence is withdrawn, for instance, the air (oxygen), or water, — as a clock stops if only a single wheel is taken from it, — so also the complete development of a plant is obstructed when one of the above-mentioned means of nourishment fails.

CULTIVATED PLANTS.

615. If we give abundant and invigorating food to an animal, it becomes vigorous and fat; on scanty and slightly nourishing food, it remains poor and lean. Just the same thing occurs also with plants. When they find an abundance of all the substances which they require for their development in the soil and in the air, they will grow up more vigorously, and put forth more branches, leaves, flowers, and fruits, than when they do not find these substances, or find only a part of them, in sufficient quantity. Consequently, the way of obtaining from our fields and meadows the largest produce consists in presenting to the plants which are to be cultivated upon them *all* the materials requisite for their nourishment in *sufficient* quantity. We do this by *manuring* the soil.

616. Nature, by means of rain and dew, decay and putrefaction, provides that the three universal means of nourishment, water, carbonic acid, and ammonia, shall not be wanting to plants; and man also, without exactly intending it, contributes his share by the act of breath*ing* and by the fires he kindles. The air contains an in-

exhaustible provision of these substances, since the processes by which they are generated on the earth never suffer an intermission. The air alone would accordingly suffice for the nourishment of plants, if they could only find in the soil the necessary inorganic salts in solution. But as a structure advances more rapidly when it is worked upon at several parts at the same time, so the growth of a plant proceeds *more rapidly and more luxuriantly* when it can take up nourishment from several different sources, not only by the leaves, but at the same time also by the roots. All vegetable and animal substances are converted by decay into water, carbonic acid, and ammonia; hence it is quite natural that such substances, when they decay in a moist soil, should promote the growth of the plants sown in that soil. Hereby is explained, *but in part only*, the beneficial influence exerted upon vegetation by the universally used animal and vegetable manures, as, for instance, the so-called humus-like substances formed from excrements, urine, horn-shavings, bone-dust, guano, straw, leaves, &c.

617. But the reception of these universal means of nourishment, and their transformation into organic matter by the vital activity of the plants, can, as already mentioned, only take place by the aid of the *inorganic salts*. If these are wanting in a soil, the seeds sown in it may indeed germinate and grow for a while, because they contain within themselves a certain quantity of those inorganic constituents which the plants require for their growth, but the growth will cease when the constituents are exhausted in the development of the young plants. Nature provides, indeed, for the formation of soluble substances in the earth, by the gradual action of the weather; but these are not sufficient to yield a rich harvest year after year from the same fields,

and it is therefore indispensable to mix these constituents artificially with the soil in order to maintain its fertility. This is done, either *directly by those mineral substances* which contain lime, potassa, soda, phosphoric acid, &c., as, for instance, by lime, gypsum, marl, wood-ashes, bone-ashes, animal charcoal, common salt, &c.; by the overflowing of meadows with water, &c.; or *indirectly, by the salts contained in most kinds of manure.* The soluble salts existing in the food are removed again from the animal body by the urine of animals, the insoluble by the solid excrements; and thus is explained, in a simple manner, why the excrements of animals fed upon oats are the most appropriate and most powerful manure for oats; those of animals fed upon peas, clover, or potatoes, the best manure for peas, clover, or potatoes. In these saline or inorganic substances consists the *second mode* of operation of the animal and vegetable manures.

Since the *different* kinds of plants require *different* inorganic substances, and *different quantities* of them, for their nourishment,—some, for instance, principally salts of potassa, others salts of lime, and others again phosphates or silicates,—so it is advantageous in the cultivation of plants to make such an *alternation* (*rotation of crops*) that a potassa plant shall be followed by a lime plant, and this again by a silica plant, &c. In this way, it is possible to obtain from a field which is exhausted for one kind of plant a second or a third crop consisting of a different species of plant, without the necessity of manuring it each time.

618. It is clear from these hints, that chemistry alone can give to the farmer a knowledge of the constituents of his soil, of the constituents of the plants which he wishes to cultivate upon this soil, and of the substances

which must be added to it in order that the plants may find there all that is necessary for their nourishment. Inducement enough is hereby offered to every farmer to cultivate a more intimate acquaintance with this science, as the only guide to be relied upon in his practical experiments and occupations.

RETROSPECT OF VEGETABLE MATTER IN GENERAL.

1. While a plant lives, a constant motion, and a constant reception, change, and surrendering of certain aeriform and liquid substances, are continually taking place in it. If these substances are wanting to the plant, its growth and life cease; we therefore regard them as food for the plant.

2. These substances all belong to the inorganic compounds; they consist, —

a.) Of a combination of hydrogen and oxygen (water).

b.) Of a combination of carbon and oxygen (carbonic acid).

c.) Of a combination of nitrogen and hydrogen (ammonia).

d.) Of inorganic acids and bases (salts).

3. From these substances are formed, in an incomprehensible manner, the juices of the plants, and from these the single parts of the plants (organs), together with the innumerable vegetable substances which we find in them.

4. The vegetable substances may be classified by different methods. We may classify them, —

I. According to their more or less general diffusion: —

a.) Into such as occur in almost *all* plants; for instance, vegetable tissue, starch, sugar, gum, mucus, fats, many acids, chlorophyll, albuminous matter, &c.

b.) Into such as occur only in *certain* kinds of plants; for instance, extractive matter, coloring matter, volatile oils, resins, many acids, organic bases, &c.

II. According to their *chemical character:* —

a.) Into vegetable acids.

b.) Into vegetable bases.

c.) Into indifferent vegetable matter.

The *indifferent* combinations predominate in the vegetable and animal kingdoms, the acids and bases in the mineral kingdom.

III. According to their *composition:* —

a.) Into *non-azotized* substances, and, moreover,

- α. into those rich in oxygen, namely, organic acids, &c.;
- β. into those rich in hydrogen, namely, fats, volatile oils, resins, &c.;
- γ. into those rich in carbon, namely, vegetable tissue, starch, sugar, gum, mucus, &c.

b.) Into *azotized* substances; for instance, organic bases, many of the coloring matters, &c.

c.) Into those *containing nitrogen and sulphur;* for instance, albumen, gluten, caseine, &c.

The *non-azotized* compounds predominate in the vegetable kingdom, the *azotized* and *sulphurized* compounds in the animal kingdom.

5. The vegetable substances produced by nature may be transformed and decomposed in various ways into new combinations. They may be *changed,* —

a.) By *the addition of oxygen;* as,

- α. by combustion with free access of air (carbonic acid, water, nitrogen);

β. by decay (humus, carbonic acid, water, ammonia, acidification of spirituous liquids, and of other vegetable substances; grass-bleaching, &c.);

γ. by mere exposure to the air (drying or becoming rancid of fats, conversion into resin of the volatile oils, &c.);

δ. by evaporation (the becoming brown of extracts, &c.);

ε. by the action of nitric acid, chromic acid, and other bodies rich in oxygen (conversion of sugar into saccharic acid, oxalic acid, &c.).

b.) By the *abstraction of oxygen* (reduction of indigo-blue).

c.) By the *abstraction of hydrogen* (bleaching with chlorine).

d.) By *combining with sulphurous acid* (bleaching with this acid.

e.) By the *abstraction of hydrogen and oxygen* (transformation of alcohol into ether or olefiant gas, and also of oxalic acid into carbonic oxide and carbonic acid by sulphuric acid; charring of wood by sulphuric acid, &c.).

f.) By the *addition of hydrogen and oxygen* (putrefaction of vegetable matter with exclusion of air, as, for instance, under water; that is, the conversion of vegetable matter into carbonic acid, carburetted hydrogen [marsh gas], water, ammonia, mud, peat, brown-coal, pit-coal; conversion of starch or sugar into lactic acid, &c.)

g.) By *heating with exclusion of air* (charring or dry distillation of wood, of pit-coal, of the fats, of the acids, &c., that is, their conversion into carbonic acid, carburetted hydrogen [illuminating gas], water, wood-vinegar [empyreumatic acids], ammonia, tar [burnt oil, burnt resin], creosote, wood-coal, coke, &c.).

h.) By the peculiar action, not yet thoroughly investigated, of an easily decomposed body or *ferment* (spirituous fermentation, that is, decomposition of sugar into alcohol and carbonic acid).

i.) By the *transposition*, not yet explained, of one vegetable substance into another *isomeric* (equally constituted) compound; for example, —

- α. conversion of starch into gum and sugar by sulphuric acid;
- β. conversion of starch into gum and sugar by diastase;
- γ. conversion of starch into gum by moderate heating;
- δ. conversion of crude sugar into liquid sugar by heating or long boiling with water;
- ε. coagulation of albumen by heating, &c.

k.) By the *operation of strong bases* upon vegetable matter; for example, —

- α. formation of cyanogen (§ 291);
- β. formation of ammonia (§ 232);
- γ. formation of nitre (§ 207);
- δ. formation of soap from fats (§ 540).

l.) By the action of light (formation of chlorophyll, bleaching of colors, &c.).

These are only a few of the more important metamorphoses of vegetable matter as yet known to us; but their extent is unlimited, and increases every day, since extraordinary industry and zeal are now devoted to the investigation of this very department of chemistry.

ANIMAL MATTER.

619. The chemical processes which take place in the living *animal* are far more mysterious and more complex than even those which take place in plants. That such actions really do occur in the animal body, who can doubt? We here see that which peculiarly characterizes these processes, the conversion of bodies into new bodies with entirely new properties, far more distinctly and more forcibly than in plants and minerals. For can there be a more striking metamorphosis than that of the constituents of the egg (albumen, yolk, and egg-shell) into the constituents of the young bird (flesh, blood, bones, feathers, &c.)? or the conversion of milk, which constitutes the sole nourishment of many young animals, into flesh, blood, &c.? That chemical force alone cannot effect these changes has already been stated in the earlier part of this work; it is merely the instrument, the means, which the Divine Power has employed, in a way as yet concealed from us, to form, *during the life* of the vegetables and animals, all the different parts of the vegetable and animal kingdom. That which principally distinguishes animal life from vegetable life is, that during the former oxygen is incessantly *inhaled*, but during the latter it is *exhaled;* and also, that, with the exception of water and some

salts, organic substances only are appropriated to the support of the former.

620. The chief mass of vegetable matter consists of non-azotized substances, consequently of substances which contain only three elements; but in the animal body, on the contrary, the *azotized* and *sulphurized substances* (albuminous substances), consequently far more complex combinations, predominate. Water and fat are almost the only substances, composed of only two or three elements, that occur in the animal body; all the others, for instance, flesh, cartilage, blood, hair, nails, &c., are rich in nitrogen, sulphur, and also in phosphorus. It is also characteristic of these substances that they do not assume a crystalline form; we find crystalline combinations — as, for instance, in urine (urea, uric acid, &c.) — in those animal liquids only, which, being unfit for assimilation, are again separated from the body. Most animal substances, when viewed under the microscope, exhibit the form of small globules. Accordingly, the globular form is the fundamental form for the composite, more highly organized types of the animal kingdom, while in the more simple, lifeless productions of the mineral kingdom, the angular form (crystalline form) prevails. In the vegetable kingdom, holding a middle position between the two, we find both forms, namely, the globular or spherical in starch, yeast, &c.; the crystalline in sugar, in organic acids, bases, &c.

621. The elementary matter from which the proximate constituents, and from which again the organs of the animal body, are formed, is exactly the same as that which occurs in the vegetable kingdom, namely, *oxygen*, *hydrogen*, *carbon*, *nitrogen*, *sulphur*, *phosphorus*, and *chlorine;* and the metallic substances, lime, potas-

sium, *sodium*, and *iron*. These must be introduced into the animal body in order that it may grow and live. How this happens may be shown most simply in the constitution of the *egg* and of *milk*.

I. THE EGG.

The egg, as is known, consists of the *albumen*, the *yolk*, and the *shell*.

622. *Albumen.* — The *white* in the hen's egg consists of cells, in which is contained a colorless alkaline liquid, the *albumen*. On evaporation, we obtain from it one eighth of solid albumen; the rest is water. When burnt, it leaves behind common salt, carbonate, phosphate, and sulphate of soda, and phosphate of lime. That albumen, when briskly beaten up, yields a porous light froth, that it becomes insoluble and coagulates by heating, &c., are well known facts. On account of the latter property, it is used for clarifying turbid liquids, especially the juices of sugar.

Experiment. — Stir up some honey in warm water, add a little albumen to the turbid solution obtained, and heat the mixture to boiling. The albumen seizes upon the foreign substances floating in the liquid, bears them to the surface, and incloses them within itself as it coagulates; the liquid thereby becomes clear and transparent, and may be separated by a strainer from the coagulated albumen.

The constituents of animal albumen are just the same as those of vegetable albumen (§ 477).

623. The *yolk of eggs* consists of albumen holding in suspension yellow drops of oil. On account of the albumen contained in it, it coagulates when heated, *and the fat* (*oil of yolk of eggs*) may be extracted from

it by strong pressure, or by agitation with ether. *Phosphorus* is contained in the oil of yolk of eggs.

624. *Egg-shells.* — *Experiment.* — Pour some diluted muriatic acid upon some egg-shells; with the exception of some membrane, they will entirely dissolve, with the evolution of gas. The gas which escapes is carbonic acid; but lime is contained in solution in the muriatic acid, as we may ascertain by the addition of sulphuric acid, which throws down gypsum from it. The shells have accordingly the same constitution as chalk, namely, they consist of *carbonate of lime.*

There are in the egg-shells small pores, through which the air penetrates into the interior of the egg, and gradually effects a change (putrefaction) of the latter. If these openings are stopped up, — for instance, by packing the eggs in ashes, or by smearing them with oil, — the eggs will keep much longer unchanged, as the penetration of the air is thus prevented.

II. MILK.

Milk consists of a solution of *caseine* and *sugar of milk* in water, in which solution small *globules of oil* are held suspended. The latter render the milk opaque, and give it the appearance of an emulsion.

625. *The Oil-Globules.* — *Experiment.* — These globules cannot be separated from the milk by filtration alone, as they are so small that they pass with it through the pores of the finest paper; but it may be accomplished in the following manner. Dissolve an ounce of Glauber salts and a couple of grains of carbonate of soda in half an ounce of lukewarm water, and agitate the solution with half an ounce of fresh milk.

If you now transfer this mixture to a filter, the fatty portions (cream) remain behind, while a liquid, only slightly opalescent, passes through. The saline solution added does not act chemically upon the constituents of the milk, but it only acts mechanically, causing the globules to form a more compact mass, and to be more readily separated from the watery liquid.

626. *Caseine.* — *Experiment.* — If you add to the filtered liquid a few drops of muriatic acid, the *caseine* separates from it as a white flaky mass; accordingly, the animal caseine is likewise coagulated and rendered insoluble by acids in the same manner as vegetable caseine (§ 452), with which it exactly agrees in constitution. Pure caseine is insoluble in water, but it dissolves in it when alkalies are present; these always exist in the milk, and keep the caseine in solution. The alkali (soda) is withdrawn from the caseine by the acids which are added, and the caseine then separates in the familiar form of new cheese. Caseine is an albuminous substance, that is, it contains, besides carbon, hydrogen, and oxygen, also some *nitrogen* and *sulphur* in its constitution.

627. *Albumen.* — *Experiment.* — If you filter the caseine from the liquid, and then boil the latter, it again becomes turbid, although less so than before. It is the *albumen* which separates, small quantities of it being present in all milk.

628. *Experiment.* — Let a small piece of the dried membrane of the stomach of a calf (*rennet*) remain standing one night in a spoonful of water, and afterwards pour this water upon a quart of new milk; the milk, after having stood for some hours in a warm place, will coagulate into a gelatinous mass, which is *to be put upon* a filter. What remains behind consists

of an intimate mixture of the curdled *caseine with globules of fat*. By pressing and drying, we obtain from it the so-called *cream* or *new-milk cheese* (Swiss, Dutch, Chester, &c. cheese).

629. *Sugar of Milk.* — *Experiment.* — Separate the filtered liquid (*sweet whey*) from its albumen by boiling, and, having again filtered it, evaporate till only a few ounces of it remain. If left in a warm place, hard, prismatic white crystals of *sugar of milk* will be deposited (§ 473). By this method sugar of milk is procured in Switzerland on a large scale. Consequently the sweet whey is to be regarded principally as a solution of sugar of milk (together with some albumen and some salts) in water.

Experiment. — Dissolve again in water the sugar of milk obtained, and put a piece of *rennet* in the solution; the liquid will soon become sour in a warm place, because the sugar of milk is converted into *lactic acid.*

630. *Experiment.* — The coagulation of the milk, which was produced by the rennet in a few hours, is effected instantaneously by the addition of *acids*, as is rendered obvious by adding a few drops of some acid to heated milk. In this curdled mass are contained all the caseine and fatty particles of the milk (cheese and butter).

631. *Experiment.* — Fill a flask with fresh milk, close it, and keep it, inverted, from twenty-four to thirty-six hours in a cool place; then loosen the stopper a little, so that the lower, thinner portion of the milk (*blue* or *skim milk*) may run off, but the upper, thicker part (*cream*) remain behind. On standing, the lighter oil-globules of the milk ascend, and form on the surface the well-known fatty, thick cream. If this is shaken for some time, the membranes of the oil-globules are torn,

and the latter then unite together, forming masses of butter. The thin milk which passes off from beneath may be separated, in the way already described, into caseine, albumen, and sugar of milk.

Butter, like the vegetable fats, consists of a solid fat (*margarine*) and a fluid (*oleine*), and it has also exactly the same properties (§ 533). But besides these two kinds of fat, butter contains a small quantity of a peculiar fat (*butyrine*). If butter remains exposed some time to the air, some volatile fat acids having a disagreeable smell and taste will be generated in it; these cause the rancidity of butter. If butter that has become rancid is boiled several times with double its quantity of water, these acids will be removed from it, and the butter, on cooling, will have regained its agreeable flavor.

632. If you let milk stand for some time in *open vessels*, its sugar of milk is gradually converted into *lactic acid*, and this, like every other acid, causes a curdling of the milk, and at the same time its well-known sour taste. But the curdling first commences after most of the oil-globules have collected on the surface (sour cream). From this cream butter is most usually prepared with us, and therefore the buttermilk remaining (a mixture of curdled caseine, lactic acid, and water, with some particles of butter remaining behind) has an acid taste. The so-called *curd* beneath the cream contains only some traces of fat, and consists accordingly of water, lactic acid, and coagulated caseine. By pressing we obtain from it the *sour whey*, and, as a residuum, the coagulated caseine, from which our common *skim-milk cheese* is made. When kept damp this undergoes a decomposition (putrefaction), by which ammonia *is generated*, which forms with the caseine a soft

saponaceous mass. If the putrefactio farther, there will be finally generated pounds of a very offensive odor (sulphu volatile fat acids, &c.).

633. *Fermentation of Milk.* — *Exper* stand in a flask till it begins to curdle, flask furnished with a tube for the (Fig. 188) in a place the temperatur from 24° to 30° C. A brisk evolu acid will commence, because the sug has not yet passed into lactic acid. higher temperature, first into grape alcohol and carbonic acid. But th at the same time some butyric acid, disagreeable taste to the spirit, obtain tion of the fermented liquid after and squeezed off. The *koumiss* pr mucs is a liquor obtained by the ferm milk.

634. *Ashes of Milk.* — If milk is of air, there remain behind, after all gen, oxygen, and nitrogen have aeriform combination, *ashes*, which soda, lime, magnesia, and sesquioxi of phosphoric acid, sulphuric acid,

635. *Digestion.* — If we reconside of the egg and the milk, as just stat the following elementary substances

The egg consists of		
Water	= H, O.	Water
Oil of eggs	= H, O, C, P.	Butter
Albumen	= H, O, C, N, S, P.	Sugar of
		Caseine
		Albumen
Shells and other in- *organic* substances	Ca, Na, K, Fe, P, S, Cl, O.	Inorganic stances

saponaceous mass. If the putrefaction advances still farther, there will be finally generated also volatile compounds of a very offensive odor (sulphuretted hydrogen, volatile fat acids, &c.).

633. *Fermentation of Milk.* — *Experiment.* — Let milk stand in a flask till it begins to curdle, and then put the flask furnished with a tube for the evolution of gas (Fig. 188) in a place the temperature of which ranges from 24° to 30° C. A brisk evolution of carbonic acid will commence, because the sugar of milk, which has not yet passed into lactic acid, is converted, at a higher temperature, first into grape sugar, and then into alcohol and carbonic acid. But there is also formed at the same time some butyric acid, which imparts a disagreeable taste to the spirit, obtained by the distillation of the fermented liquid after it has been strained and squeezed off. The *koumiss* prepared by the Calmucs is a liquor obtained by the fermentation of mare's milk.

634. *Ashes of Milk.* — If milk is burnt with access of air, there remain behind, after all its carbon, hydrogen, oxygen, and nitrogen have been converted into aeriform combination, *ashes*, which consist of potassa, soda, lime, magnesia, and sesquioxide of iron, and also of phosphoric acid, sulphuric acid, and chlorine.

635. *Digestion.* — If we reconsider the constituents of the egg and the milk, as just stated, we find in them the following elementary substances: —

The egg consists of		Milk consists of	
Water	= H, O.	Water	= H, O.
Oil of eggs	= H, O, C, P.	Butter Sugar of milk	= H, O, C.
Albumen	= H, O, C, N, S, P.	Caseine Albumen	= H, O, C, N, S, P.
Shells and other in*organic* substances	Ca, Na, K, Fe, P, S, Cl, O.	Inorganic substances	=Ca, Na, K, Mg, Fe, P, S, Cl, O.

But exactly the same, and only the same, elementary substances are found also in the animal body; accordingly, it must be concluded that the constituents of the hen's egg are used, in the hatching of the egg, for the development of the young chicken, and the constituents of the milk which forms the food of the young Mammalia are used for the growth and nourishment of the latter. It is the same, also, with the constituents of the vegetable and animal substances, which serve us as *food*. The food is mixed up in the stomach with the *gastric juice* (a liquid containing free *muriatic acid* and common salt, which liquid is secreted by the inner skin of the stomach, — *mucous membrane*), and is thereby softened into a soluble, white, pulpy mass (chyme). The muriatic acid is likewise formed by a decomposition of common salt taking place in the body, and it is indispensable for the solution (digestion) of the food. The explanation of this action is, that water, rendered feebly acid by muriatic acid, is able (after it has been previously left in contact for a day with a piece of rennet) to dissolve, at a temperature of from 30° to 40° C., hard-boiled albumen, flesh, and other food. All of the chyme which has become soluble is, during its passage through the intestines, absorbed and introduced as nourishment (chyle) into the blood. The changes which the food experiences in the animal body are therefore the following: from the food is formed chyme, from this chyle, from this blood, and from the blood all the numerous organs and parts of the animal body are generated, just as all the organs and parts of plants are generated from the vegetable juices.

III. THE BLOOD.

Like milk, the blood also consists of a liquid as clear as water, in which small globules are held suspended; but these globules (blood corpuscles) have, however, a yellowish-red color.

636. *Experiment.* — If you let the blood of an animal remain standing quietly in a vessel, it will, in a short time, undergo a change; it coagulates, forming a dark-red jelly (*the clot*, *coagulum*), which contracts on longer standing, and a yellowish-liquid is separated (*serum*). When the latter is heated to boiling, it coagulates to a white jelly; the serum consists of a solution of *albumen.* There are two substances combined together in the coagulum, one of which dissolves by long washing in water, communicating to it a red color (*coloring matter of the blood*, the principal constituent of the blood corpuscles), while the other remains behind as a white fibrous mass (*animal fibrine*). Accordingly, the most important proximate constituents of the blood are water, albumen, blood corpuscles, and animal fibrine, which, on the standing of the blood, are transposed in the following manner: —

$$\text{From} \quad \underbrace{\text{Water, Albumen,}}_{\text{Serum}} \quad \underbrace{\text{Blood Corpuscles, Fibrine,}}_{\text{Coagulum.}}$$

are formed Serum and Coagulum.

It is a distinguishing peculiarity of the coloring matter of the blood, that it always contains iron.

637. *Experiment.* — If the blood freshly drawn from the veins is beaten up during cooling, it does not coagulate; the *fibrine* is indeed insoluble, and exists as a thread-like coherent mass, which, when kneaded for some time with water, becomes finally white, and, after drying, resembles the muscular fibre. In-

deed, it may be regarded as half-formed flesh, since it has entirely the same composition, and at any rate the flesh of the animal body is formed from it. The blood remaining behind retains, after the separation of the fibrine, its red color, and coagulates on boiling to a jelly of a dark-red color, as may be perceived in the so-called *black-pudding*.* The metamorphosis of the blood just treated of is, accordingly, as follows:—

$$\underbrace{\text{Water, Albumen, Blood Corpuscles}}_{\text{remain liquid.}} \qquad \underset{\text{becomes solid.}}{\text{Fibrine}}$$

Fibrine belongs to the albuminous substances; it is very rich in oxygen, and contains also sulphur and phosphorus in organic combination.

638. *The Ashes of Blood.*—If blood is evaporated to dryness, and heated for a long time in the air, it will finally burn up, with the exception of some ashes. These ashes consist of alkaline phosphates (much soda, little potassa), phosphates of the alkaline earths (lime, magnesia), phosphate of the sesquioxide of iron, common salt, and the alkaline sulphates; consequently, of the same constituents which we find in the ashes of our principal articles of nourishment (eggs, milk, bread, &c.). In the vegetable kingdom we find these ash-constituents most abundant in those vegetable parts which are rich in albuminous matter, especially in the seeds of our grains and leguminous plants.

639. *Respiration and Means of Nourishment.*—As long as an animal lives, its blood is in a state of constant motion and of constant change. Light-red blood streams out from the heart, through the arteries, into all

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* "Mixed with fats and aromatics, and inclosed in the prepared intestines, the blood of this animal [the pig] constitutes the *sausages* sold in the *shops under the name of black-puddings*."—Pereira on Food and Diet.

parts of the body, from which it returns, darker colored, through the veins, back again to the heart. But before the latter blood recommences its circulation, it is impelled through the lungs, in which it comes in immediate contact with the inhaled air, and by means of which it experiences a most remarkable change. When in contact with the air, the dark venous blood is converted again into light-red arterial blood, and thereby the *air loses a part of its free oxygen, and receives in return carbonic acid and vapor;* the exhaled air is accordingly poor in oxygen, but rich in carbonic acid and vapor. This change of the air is obviously very much like that which the air undergoes by the process of combustion; for in this case, too, its free oxygen is converted into carbonic acid and water. Indeed, this similarity is rendered still more apparent, when we consider, moreover, that *heat becomes free* also in the animal body, as long as it lives and breathes, and that the food received into it, like wood in the stove, entirely disappears, with the exception of a small portion which passes off in the form of excrements. Its disappearance takes place in exactly the same way as that of wood, with which we heat our apartments; this disappearance is caused by a change of the food into aeriform combinations, into carbonic acid and vapor, which are partly exhaled by the lungs, and partly evaporated from the skin.

For this purpose, as it seems, non-azotized food, namely, starch, sugar, gum, fat, lactic acid, and other organic acids, beer, wine, &c., are principally employed, and are therefore called *elements of respiration.*

It is different with those substances which contain nitrogen and sulphur (and phosphorus); these serve for the production of blood, the constituents of which are the same. These substances, albumen, fibrine, &c.,

afterwards pass with the blood into all parts of the animal body, and are transformed into flesh, nerves, muscle, hair, nails, &c. For this reason, they have been called the *plastic elements of nutrition.* Those azotized, sulphurized, and other substances, such as salts, which can no longer be used in the animal body, are removed from it again by the solid excrements and the urine.

IV. THE FLESH.

What is commonly called *meat* (muscle) is likewise (see § 637) *animal fibrine* or *muscular fibre.* In this form it consists of bundles of fine fibres, which are interwoven with cellular tissue, nerves, and veins, and are thoroughly penetrated with a watery liquid, the so-called juice of flesh.

640. *Juice of Flesh.* — *Experiment.* — Mince a quarter of a pound of lean meat very fine, pour over it a quarter of a pound of water, and, after letting it stand fifteen minutes, press out the liquid through a linen cloth; pour over the residue the same quantity of water, squeeze out the liquid, and mix this with the former liquid. In the reddish *juice* are contained almost all the soluble, and, at the same time, all the savory and odorous constituents of the flesh. If this juice is heated to 60° C., a frothy mass separates from it, which consists of coagulated *albumen.* When the liquid filtered off from this is boiled for some time, a turbidness again ensues, which is caused by the *coloring matter* and *fibrine* (§ 636) of the blood extracted also from the flesh, which likewise coagulate at a boiling heat. The acid broth or decoction (*bouillon*) now remaining behind contains free phosphoric and lactic acids, phosphate and

lactate of the alkalies (much potassa, little soda), phosphate of magnesia, together with several organic matters, a crystalline, indifferent organic body (*creatine*), and a crystalline, basic, organic body (*creatinine*), neither of which has been yet thoroughly investigated. By evaporation the broth becomes yellow, and finally brown (*roast-broth*); if evaporated to dryness, a dark-brown soft mass (*extract of flesh*) remains behind, half an ounce of which is sufficient to convert one pound of water, to which some common salt has been added, into a strong and savory soup.

641. *Fibrous Tissue.* — *Experiment.* — If you boil the fleshy residue left after the former experiment with water for some hours, you obtain a liquid which coagulates in the cold to a jelly, and consists principally of a solution of *gelatine;* the fat floating on the surface proceeds from the tallow, or fat of the flesh. What remains is *fibrous tissue*, a milk-white, hard, tasteless, and odorless fibrous mass; in this hardened state it is difficultly digestible, and but slightly nutritious.

The annexed grouping gives a probable idea of the *quantitative* composition of the flesh. From one thousand pounds of beef were obtained, —

a.) By expression with water (consisting one half of albumen), . . .	60 lbs.
b.) By five hours' boiling with water (consisting chiefly of gelatine), . .	6 "
c.) Lean, juiceless, and tasteless fibrine, .	164 "
d.) Fat or tallow, ...	20 "
e.) Water, ...	750 "
	1000 lbs.

642. *Boiling of Meat.* — To obtain by boiling an excellently tender, savory, and nutritious meat, care must

be taken that the juice is *not* extracted from the flesh during boiling, but remains in it, and that the boiling is not continued too long. If the *albumen* contained in the juice remains in the interstices of the animal fibres, a tender roasted or boiled meat is obtained; but if, during the boiling or roasting, the juice goes into the broth or gravy, then the meat becomes tough and hard. It is best to put the meat to be boiled into boiling water, continue the boiling for several minutes, and then let it stand for some hours in the kettle on the hearth of the stove, where the temperature is about 70° C. In this way the albumen in the external layers of the meat is immediately coagulated by the boiling water, and forms, in this coagulated state, a coating which prevents the escape of the liquid, and likewise the penetration of the external water into the interior of the meat.

643. *Preparation of Broth, or Soup.* — We must manage in just the contrary way if we wish to obtain a good and abundant soup from the meat. To effect this, mince the meat fine, mix it uniformly with an equal weight of cold water, heat it slowly to ebullition, let it boil for a few minutes, and finally strain off and squeeze out the liquid. By adding to this liquor some common salt, and other ingredients with which soups are commonly seasoned, and then coloring it somewhat darker with onions burnt brown, or with burnt sugar, to give it the ordinary favorite brownish color, we obtain the best soup which can, in general, be prepared from a given quantity of meat. Hitherto, it has been frequently assumed that gelatine formed the most important, most characteristic constituent of animal soup; but this is a mistake, since the gelatine itself is quite tasteless, and forms but a very insignificant part of the

soup. And for this reason, the so-called portable soup prepared in England and France cannot yield a really good animal broth.

644. *Salting of Meat.* — A universally known method of preserving meat is to salt it down, that is, to rub into it and strew over it some common salt, and let it remain piled up, or pressed together, for some time. The common salt extracts from the flesh one third to one half of the juice, dissolves in it, and forms with it the so-called *brine*. Since, consequently, a large portion of the nutritive albumen, and of the lactates and phosphates essential to digestion and nourishment, and also of the creatine and creatinine, are removed with this brine from the meat, the latter must lose in nutriture, and it is not improbable that this is the reason why a long continued dieting on salt meat — for instance, during sea-voyages — is followed by scurvy and other maladies. Hence, it would be better not to let the salting of the meat continue till a brine is formed.

V. THE BILE.

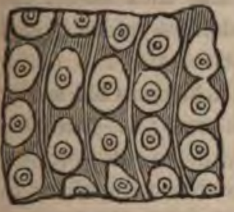
645. The bile separates in the liver from the venous blood; it consists of a thickish, greenish-yellow liquid, and possesses a very bitter taste. Its chief constituents are *choleic acid* and *soda*, which, combined with each other, have a saponaceous character. If you shake up bile with water the solution froths like soap-suds; it also comports itself like this towards greasy substances, and therefore is frequently used for washing silks, which, by the application of soap, would lose their color. The dried gall-bladder of the carp forms an article of commerce.

Experiment. — Dissolve a little *carp-gall*, or some drops of fresh ox-gall, in a little water, and add gradually to the solution sufficient common sulphuric acid entirely to redissolve the precipitate formed; if you now add a few drops of sugared water, or thin starch-paste, the liquid, unless rendered too hot by the addition of sulphuric acid, assumes a splendid violet-color. In this way, extremely small quantities of sugar or starch, or, inversely, of bile, may be detected.

VI. THE SKIN.

646. The whole body of the animal is externally surrounded by the solid elastic *skin*, which consists of a thick tissue of cells, between which are small openings (pores). The annexed figure represents a piece of human skin about the size of a mustard-seed, as it appears under a powerful magnifying-glass. Partly an oily substance, and partly a watery perspiration, together with some carbonic acid, are separated from the body through the pores.

Fig. 219.



Experiment. — Put a piece of fresh animal skin in water; it swells up in it without dissolving; if kept for some time, it passes over into an offensive putrefaction. If, however, the skin is boiled for some hours with water, the largest part of it dissolves, and we obtain a liquid which, on cooling, *coagulates into a tremulous jelly.* When dried, this forms the well-known *glue*. The skin does not contain glue ready formed, but a tissue, which first, after long boiling, passes over into glue, and has received the name of *gelatinous tissue.*

647. *Gelatine* forms a principal constituent of the animal body, for it is found in almost all parts of it which do not belong to the albuminous substances; for instance, in the interior skin, the muscles, the tendons and ligaments, the bones, horns, &c. Its composition is very nearly that of albumen or animal fibrine; like these, it is *very rich in nitrogen*, and contains also some sulphur, but it is distinguished from them essentially by its properties, and its behaviour towards other substances.

Glue. — The common, amorphous glue is mostly prepared from refuse skins or bones, either by extraction with hot water, or, better, by the pressure of steam (digesting). The concentrated hot solution is then allowed to settle, and the thin liquor yields, on cooling, a stiff jelly, which is cut by wires into thin cakes, and placed to dry upon packthread nettings, which give it the well-known grooved appearance.

Experiment. — If you allow glue to lay in cold water, it swells up into an opaque soft mass; if you then heat it, you obtain a complete transparent solution, which, even when a hundred times diluted, stiffens on cooling. The application of glue as an adhesive medium is well known; its adhesive power is much increased by adding to it white lead (Russian glue) or borax (about an ounce or an ounce and a half to a pound of glue).

Isinglass, also, is one of the gelatinous substances. This consists of the inner skin of several fishes, particularly of the sturgeon, which, after being cleansed, is dried and brought into the market in the form of plates, or of sticks twisted into the shape of a horseshoe. On boiling, a colorless or odorless gelatinous solution is obtained from it, which is much used as an adhesive medium, or when smeared upon taffety as court-plaster, or mixed with the juices of fruits and sugar for the preparation of jellies.

The *antlers of the deer* are likewise rich in gelatine, and on this account, when rasped, yield, by long continued boiling with water, a liquid which stiffens in the cold (hartshorn jelly).

Small quantities of gluten occur also in broth, and in roast-broth, and impart to them, especially to the latter, the property of stiffening in the cold to a tremulous jelly.

648. *Gelatine and Tannic Acid.* — *Experiment.* — If you pour some tincture of galls upon a solution of gelatine, or upon a decoction of meat, you obtain a flaky precipitate, a combination of gelatine with tannic acid, which is insoluble in water, and may remain exposed to the moist air without passing into putrefaction. For this reason, gelatine is an excellent means for clarifying liquids, for instance, wine, &c., from any tannin that they may contain.

But this action of tannic acid upon gelatine is of far more importance, as it may be used for converting animal skins into *leather*. The gelatine of the skin is thus altered, as the gelatine in the experiment was, when the skins are packed in layers with ground oak or pine bark (tan) in vats, and allowed to remain moistened with water till they are quite saturated with the brown tannin of the bark (*tanning*). This penetration takes place more rapidly by forcibly pressing the liquid containing tannin into the skin (*quick-tanning*). The brown sole and upper leather consist, accordingly, of cellular tissue, the gelatine of which has become intimately combined with the tannic acid; it is now, especially when it is saturated with oil or fat, pliable, supple, and almost impervious to water; nor when moist does it undergo putrefaction.

Skins are converted in another manner into leather, by means of certain salts, most frequently by laying them in a solution of alum and common salt, and afterwards working them with fish-oil and other fats; the leather prepared in this way is white, and is softer and more supple than the former (*tawing*). The still softer *wash* or *chamois leather* is obtained by working the skins a long time with fat. In this way the Indians also convert the skins of animals into soft leather, by kneading them with the brains of animals that have been steeped in hot water, until the fat contained in the brains has been absorbed by the skin.

If the softened and scraped skins are stretched in frames, and rubbed, while drying, with pumice-stone, till they are quite smooth, the thin, translucent, stiff, and elastic *parchment* is obtained (*hog-skin*). By rubbing with chalk, the parchment becomes white and opaque, by smearing with white lead and varnish, polished and smooth (*writing-parchment*).

649. Before the animal skins can be subjected to either of the operations just described, they must be *freed from the hair*. This is easily done by scraping, after the skin has been decomposed either by the influence of moisture and heat, or by caustic potassa. Sulphuret of calcium may also be used for this purpose (§ 405).

650. Gelatine, like other animal substances in the presence of air and water, very readily passes into *decay* or *putrefaction*, and yields thereby, since it is very rich in nitrogen, much ammonia; therefore it will not appear strange that it powerfully promotes the growth of plants. Its effect may be observed in a truly sur-

prising manner in the hyacinth, if it is occasionally watered with a thin solution of glue, or if the bulbs are surrounded with horn-shavings when planted in the earth.

651. If gelatine is boiled for some time with potassa lye, there is formed from it, together with some other products of decomposition, a peculiar substance, crystallizing in needles; it has a very sweet taste, and has received the name of *sugar of gelatine*, or *glycocoll.*

652. There is a kind of gelatine which varies somewhat in its properties from common gelatine; it is obtained from young, not yet fully hardened bones, and from the cartilaginous parts of the animal body, — for instance, from the cartilages of the windpipe, of the nose, &c., — by long boiling with water. This kind of gelatine has received the special name of *chondrine.*

653. *Horny Matter.* — The hair, wool, bristles, feathers, nails, claws, hoofs, horns, scales, &c., which often cover the skin of animals, are not dissolved by boiling with water into gelatine; they very much resemble the latter in their constitution, but, besides nitrogen, they contain also some sulphur. Their containing sulphur is the reason why they become black, when heated with a solution of lead, since a dark sulphuret of lead is formed. *Wool* consists of hollow yellowish tubes, covered with fat. By washing with putrid urine, or soap-water, the fat may be removed; but by sulphurous acid the yellow color is converted into white (chlorine is not applicable to the bleaching of wool). The fibres of wool, as well as those of silk, likewise having an animal origin, have a far greater affinity for coloring matter than the vegetable fibres linen or cotton have; and this is the reason why woollen and silk stuffs may be more easily or permanently dyed than cotton or linen.

By boiling with lye, all the above-named animal substances, consisting of horny matter, may be entirely dissolved.

VII. THE BONES.

The bones forming the solid skeleton of the animal body consist, one third of organic gelatinous matter, and two thirds of inorganic matter (bone-earth).

654. *Bone-earth.* — *Experiment.* — Put a piece of beef-bone, which has been weighed, into a furnace-fire, and take it out again when it has entirely recovered its white color; the gelatine burns up, but the bone-earth remains behind. The *bone burnt to whiteness*, which has become one third lighter, consists principally of phosphate of lime mixed with some carbonate of lime (magnesia, fluoride of calcium, and chloride of sodium). This proportion between gelatine and bone-earth is, however, not unchangeable; it varies in different animals, and indeed even in one and the same animal, according to its age.

655. *Bone-black.* — *Experiment.* — If you heat a bone for some hours in a crucible which is well covered with a piece of slate, it assumes a black color; it becomes *bone-black* (ivory-black, &c.). As the air in such cases does not have access to the bones, only an imperfect combustion takes place, a charring of the gelatine; the bone-earth, intimately mixed with the carbon, remains behind.

Experiment. — If you add some *diluted muriatic acid* to the bone-black, and let it remain some time in a warm place, the bone-earth will be dissolved, and the carbon may be separated by filtration, washed, and dried. From one ounce of bone-black only half or three fourths of a dram of carbon is obtained; but this, on account of its minute state of division, possesses such a striking bleaching power, that one ounce of bone-black acts far more powerfully than the same quantity of wood-coal. If ammonia is added to the filtered liquid, the dissolved phosphate of lime is again precipitated from it as a white powder, because the muriatic acid is neutralized by the ammonia, and thereby loses the capacity of holding the bone-earth in solution.

656. *Experiment.* — Put a bone in a glass vessel, and pour over it some *diluted muriatic acid*; the bone will gradually become soft and transparent, and finally pass into a cartilaginous translucent mass. The way in which the muriatic acid acts is obvious from the former experiment; it dissolves the bone-earth, and the gelatine remains behind, since it is insoluble in muriatic acid and in water. If the gelatine is taken from the acid, and, after having been washed, is boiled for some time with water, it passes over into glue, and a solution is obtained which coagulates on cooling. This method is employed in many factories for preparing glue from bones. The acid solution of bone-earth makes an excellent manure. That bone-earth is in fact dissolved in the acid is readily ascertained by the addition of ammonia.

657. In *boiling out the bones* with water, not only the fat present in all bones, but also the gelatine lying in the external part, is extracted, and the latter may be entirely extracted when the boiling is performed in tight vessels, as in this case the water is forced by the increased pressure into the interior of the bones. Steam, also, at a great tension, operates in the same way. Glue is prepared on a large scale, according to both of these methods.

658. *Bone-dust.* — Unburnt bones ground to a coarse powder (*bone-dust*), and also white or black burnt bones, have for many years been regarded in England as an excellent manure; in Germany it is only in more recent times that their economical value has been recognized. It is very obvious how they enhance the fertility of land; the burnt bones furnish the soil, by means of the bone-earth, with two inorganic substances, *lime* and *phosphoric acid*, which every plant requires for its development; the unburnt bones, moreover, by means of their gelatinous matter, furnish *ammonia*.

VIII. THE SOLID EXCREMENTS AND URINE.

659. Those ingredients of the food consumed, which are not applicable to nourishment, that is, which cannot be converted into the constituents of the animal body, and those parts which are separated from the body (as no longer serviceable to the vital process) by the incessant process of renovation, which we call life, are either removed from the body in an aeriform state, by *breathing* or *insensible perspiration*, or in a liquid form, as urine, or, finally, in a solid form, that of the *solid excrements*. Both of the last-named substances are of great consequence in medicine and domestic economy; in medicine, because the physician, in cases of sickness, is frequently able, by their condition, to ascertain the nature of a disease; in domestic economy, because the farmer makes use of them for promoting the growth of plants.

The *solid excrements* (fæces) consist, for the most part, of those constituents of the food which are not dissolved in the stomach, — not digested; in the her bivorous animals, principally of vegetable tissue, chlorophyll, wax, and insoluble salts; in the carnivorous animals, dogs, for instance, frequently almost wholly of inorganic substances, as phosphate of lime, magnesia, &c., mixed with but a very small quantity of organic matter. The beneficial influence of solid excrements on vegetation is principally owing to the inorganic compounds contained in them (lime and magnesia, phosphoric acid, and silicic acid).

660. By the *urine*, which is separated in the kidneys from the arterial blood, the *soluble salts* contained in food, and also the *nitrogen*, no longer necessary for the vital process, are removed again from the body; it is natural, therefore, that the constituents of it, as likewise of the fæces, should correspond exactly with the food consumed. If this is rich in soluble salts, the urine will also be rich in them; if this contains only a few soluble, but many insoluble salts, the urine will be poor in soluble salts, while the fæces will be rich in insoluble salts. Consequently, the amount of inorganic substances in the animal excrement or manure may be just as accurately ascertained from the food which the animal consumes, as from the manure itself. The food has only to be burnt, and the remaining ashes examined; those parts of it which are soluble in water correspond with the salts in the urine; those which are insoluble, to the organic substances of the fæces. We find in the urine of cows and horses principally alkaline carbonates, muriates, and sulphates (potassa, soda, and ammonia); in the urine of men, moreover, some alkaline phosphates.

661. *Nitrogen* is contained in the urine, either in the form of urea, uric acid, or hippuric acid. Urine, like the juice of flesh, contains, moreover, creatine and creatinine (§ 640).

Urea occurs in the greatest abundance in the urine of the higher animals, especially in the carnivorous quadrupeds. It crystallizes in colorless needles, or prisms, and is easily soluble in water. This substance has excited great scientific interest, as it is the first organic compound which has been artificially prepared. Thus, it was found that *cyanate of ammonia*, without losing any of its constituents, or receiving any new ones, was converted merely by heat into urea.

$$\begin{array}{rl} \text{From Cyanic Acid} = & \text{Carbon, Oxygen, Nitrogen,} \\ \text{and Ammonia} = & \underbrace{\hphantom{\text{Carbon, Oxygen, }}\text{Nitrogen, Hydrogen,}}_{\text{Urea.}} \\ \text{was formed} & \end{array}$$

In a practical point of view, that decomposition which urea undergoes in urine, when the latter putrefies by long standing in the air, is of great importance. During this decomposition, the urea combines with the constituents of two atoms of water, and becomes thereby *carbonate of ammonia;* from

$$\begin{array}{rlll} \text{Urea} = & \text{Carbon, Oxygen,} & & \text{Nitrogen, Hydrogen,} \\ \text{and Water} = & \underbrace{\hphantom{\text{Carbon, }}\text{Oxygen,}}_{\text{Carbonic Acid}} & \text{and} & \underbrace{\hphantom{\text{Nitrogen, }}\text{Hydrogen,}}_{\text{Ammonia.}} \\ \text{are formed} & & & \end{array}$$

662. *Uric acid* (*lithic acid*) predominates in the urine of the lower animals; the white excrements of birds and snakes (a mixture of fæces and urine) consist chiefly of urate of ammonia. In the pure state, it consists of fine white crystalline scales, which are dissolved in water only with extreme difficulty. On account of this difficult solubility, they sometimes separate spontaneously from the urine (gravel and urinary calculi). If the excrements, which are rich in uric acid, are allowed to remain for some time exposed to the air they will absorb oxygen, and afterwards contain *oxalate of ammonia;* if the latter takes up more oxygen, it

passes over into *carbonate of ammonia*. Thus is explained why we frequently find in some sorts of guano only traces of uric acid, but instead of it large quantities of oxalates.

663. *Guano (bird-manure)*. — Guano, which in recent times has been in such demand as a manure, owes its efficacy in part to the *uric acid* contained in it, or, in so far as this has already undergone decomposition, to the *ammoniacal salts* formed from it, and in part also to inorganic *salts* (sulphate, phosphate, and muriate of potassa, soda, lime, magnesia, &c.) present in it. On account of the great difference in the article, it is indispensable that the farmer should test it before its application. This is done with sufficient accuracy for agricultural purposes in the following way.

Experiment a. — Pour some strong vinegar over guano; no perceptible effervescence should ensue. A brisk effervescence would indicate an admixture of carbonate of lime.

Experiment b. — Heat half an ounce of guano in an iron spoon over an alcohol lamp, or upon glowing charcoal, till it is burnt to a white ashes; good guano should only leave behind, at the most, one dram of ashes. How much alkaline salt this ashes contains may be ascertained by extraction with hot water; what remains are earthy (lime and magnesia) salts.

Experiment c. — Treat half an ounce of pulverized guano several times with hot water, and decant the liquid after it has become clear on settling; then dry and weigh the muddy mass which finally remains; it should not weigh more than a quarter of an ounce.

664. *Hippuric Acid.* — This azotized acid always occurs in the urine of herbivorous animals; it crystallizes in long white needles, and is difficultly soluble in water.

On the putrefaction of the urine, it is converted into benzoic acid and ammonia.

Human urine contains the above-named compounds rich in nitrogen, — urea, uric acid, and hippuric acid; the first, urea, in the largest quantity.

665. When urine remains for some time exposed to the air, it undergoes a decomposition, by which volatile substances having a disagreeable odor are formed; it passes into *putrefaction*. It is obvious from what has been stated, that *carbonate of ammonia* is to be regarded as the principal product of this decomposition (putrid urine contains, moreover, creatine). Putrid urine may, therefore, be employed for the cleansing of wool, and for the preparation of chloride of ammonium (§ 233). This change takes place when the urine is collected in manure-heaps, or is poured upon the soil. To prevent the evaporation of the volatile carbonate of ammonia, it is well to add gypsum, diluted sulphuric acid, or green vitriol, from time to time, to the manure-heaps, by which means sulphate of ammonia is formed, which does not escape at the ordinary temperature. In this respect, also, an addition of substances rich in carbon, for instance, bone-black, earthy-brown coal, peat, &c., acts very beneficially, because the coal first retards the putrid decomposition, and afterwards retains the gases hereby formed (carbonic acid, ammonia, sulphuretted hydrogen, &c.). The inorganic salts of the urine, and of the solid excrements, are not essentially changed by the putrefaction. To these *salts* and to the *nitrogen* are principally to be ascribed the beneficial effects which animal manure exercises on the fertility of our fields.

RETROSPECT OF ANIMAL MATTER IN GENERAL.

1. A constant motion is taking place in the living animal, as well as in the living plant,—an incessant receiving (eating, drinking, and breathing), changing (digestion, assimilation), and separating (secretion, excretion) of aeriform, liquid, and solid bodies.

2. In a chemical point of view, *animal life* is distinguished principally from vegetable life by the uninterrupted reception of oxygen, and separation of carbonic acid and water. (Among the Infusoria, however, there are some which exhale oxygen.) During the life of *plants*, on the contrary, carbonic acid and water are received, and oxygen separated.

3. Besides water, air, and some salts, those substances only serve for the nutrition of the animal body which are produced by means of vegetable or animal life. The plant consumes carbonic acid, the animal vegetable tissue, sugar, gum, fat, &c.; the plant consumes ammonia, the animal albuminous substances, for instance, gelatine, albumen, caseine, flesh, blood, &c.

4. The first series of the above-named means of nourishment, those rich in carbon, serves for the maintenance of the respiratory or destructive processes, and for the generation of animal heat (elements of respiration); the second class, that of the means of nourishment rich in nitrogen, serves for the maintenance of the nutritive or formative process (plastic elements of nutrition).

5. Animal substances may be divided:—

I. According to their *composition*,—

a.) Into non-azotized substances (fat, sugar of milk, &c.).

b.) Into azotized, albuminous substances (albumen, caseine, flesh, fibrine, &c.).

c.) Into azotized gelatinous substances (gelatine of the bones, ligaments, gristle, &c.).

d.) Into azotized excretory substances (urea, uric acid, hippuric acid, &c.).

II. According to their *occurrence* and their *production* in the animal body, —

a.) Into products of the process of digestion.
b.) " " " " breathing.
c.) Constituents of the red blood.
d.) " of the white blood (lymph).
e.) " of the flesh, &c.
f.) " of the bones, &c.
g.) " of the skin, hair, &c.
h.) " of the secretory and excretory products (gall, milk, urine, &c.).

6. *The changes of animal matter* by the influence of heat, water, air, acids, bases, &c., exceed in variety those of vegetable matter, since they are far more complex than the latter; they mainly agree with those which the azotized and sulphurized vegetable substances experience.

7. The spontaneous changes of animal and vegetable matter may be arrested, —

a.) By removal of the *water* (drying, baking, &c.).

b.) By exclusion of *air* (Appert's method of preservation, bottling of beer, wine, &c.).

c.) By reducing the *temperature* below the freezing point (refrigerators, &c.).

d.) By antiseptics; for instance, common salt, nitre (salting), wood-vinegar, creosote (smoking), alcohol, sugar, charcoal, and arsenical, mercurial, and other metallic compounds.

THE END.

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